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MAP OF NORTH-CENTRAL KENTUCKY AND ADJACENT PARTS OF OHIO AND INDIANA.

Areas underlaid by Silurian strata, either exposed or covered by Devonian and later formations, indicated by dots. Areas in which Silurian strata are absent are left blank. Areas in which the Clinton is absent occur between Dupont, Westport and Osgood in Indiana.

Kentucky Geological Survey,

CHARLES J. NORWOOD, Director.

BULLETIN No. 7.

The Silurian, Devonian and Irvine Formations of East-Central Kentucky,

WITH
AN ACCOUNT OF THEIR CLAYS AND LIMESTONES.

Preliminary Report by
AUG. F. FOERSTE.

Office of the Survey: Lexington, Ky.

1906

PRINTED BY THE GEO. G. FETTER COMPANY, LOUISVILLE, KY.

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Letter of Transmittal.

To His Excellency, J. C. W. BECKHAM,
Governor of Kentucky.

SIR: I have the honor to herewith transmit for publication a bulletin, prepared by Professor Aug. F. Foerste, on the Silurian, Devonian and Irvine Formations of East-Central Kentucky, with an account of their clays, limestones, mineral waters and water horizons.

The report is divided into three parts. Part I. deals with the classifications of the several formations, and with the geographic distribution of their subdivisions, in accordance with the better knowledge of them that has been acquired since the earlier work of William M. Linney (deceased). The great excellence of the pioneer work of Mr. Linney on the Kentucky Silurian (then known as Upper Silurian) is heartily conceded by all who are acquainted with the subject; but the urgent necessity for a classification which will accord with more recent knowledge and present terminology is well recognized by all geologists who have worked or who expect to work in Kentucky regions where Silurian or Devonian rocks form the substructure of the ground. The usefulness of a correct classification of our rocks—the bearing it has upon the study of the economic geology of the State—has been discussed in my Report of Progress for 1904-'05. The numerous sections and page maps, showing the distribution of various members of the formations, will prove of much value in connection with the preparation of the soil map of the State. Professor Foerste has taken pains to give full lists of fossils which characterize the more important beds, thus rendering his report of especial service to local investigators.

Part II. deals with the economic values of the formations

under consideration. In this section is discussed, among other subjects, the availability of Devonian and Silurian clays and limestones for the manufacture of cements. A good foundation is here laid for the technological investigations that are to follow in due course.

In Part III. are given descriptions, with plates, of some of the fossils that characterize the principal Silurian beds referred to in the preceding parts of the report. The local worker will find this a very useful feature of the bulletin, since it will enable him to discriminate individual beds of the formation, and teachers in the advanced schools of the State will find it helpful in their work.

Very respectfully,
C. J. NORWOOD,
State Geologist.

Addendum.

This report was prepared for publication in 1905, but various causes have delayed its passage through the press. This has not been altogether unfortunate, since it has enabled Professor Foerste to include notes on some observations made in 1906, the date which the title page now bears.

Letter of Submittal.

PROFESSOR CHARLES J. NORWOOD,

Director, Kentucky Geological Survey.

SIR: I have the honor to submit herewith a report on the Silurian and Devonian formations of East-central Kentucky, with an account of the economic availability of their clays and limestones. To this is added a brief discussion of the Irvine formation, which includes the extensive clay deposits used for the manufacture of pottery at Waco and Bybeetown or Portwood, in Madison county. The report is of necessity merely preliminary to further investigations, since the field work of the last season has left many questions of stratigraphic and economic interest unanswered. In the investigation of the Red river area I was materially assisted by John Goff, a resident at Indian Fields.

Respectfully,

AUG. F. FOERSTE,

Assistant Geologist.

Dayton, Ohio, Nov. 1, 1905.

Preliminary Table of Paleozoic Formations.

SYSTEM.	SERIES.	FORMATION.	THICKNESS.		MEMBER.	THICKNESS.
Pennsylvanian.	**Coal Measures.** **Conglomerate Measures.**					
Mississippian.	**Lower Carboniferous** **Shales, Sandstones and Limestones.** **Waverly.**					
Devonian.		Ohio black shales.	20-135			20-135
		Boyle limestones.	0 47		(West-Central Ky.) Sellersburg. Jeffersonville. Geneva.	0-47
Silurian.	Niagaran.	Crab Orchard.	110 to 180	Alger.	Estill. Waco. Lulbegrud.	65-120 8-10 10-13
				Indian Fields.	Oldham. Plum Creek.	10-14 5
		Clinton.	13-19		Brassfield.	13-19
Ordovician.	Cincinnatian.	Richmond.	140-210		Saluda.	20-40
				Versailles.	Whitewater. Liberty.	70-100
					Waynesville.	50-70
		Maysville (Lorraine.)	280	Kentucky river limestone of N. S. Shaler.	Arnheim. Mount Auburn. Corryville. Bellevue. Fairmount.	50 20 60 20 80
				Upper Garrard	Mount Hope.	50
		Eden.	160-260	LowerGarrard.	Paint Lick.	40-60
				Million (Upper Winchester.)	Middle Eden. Lower Eden.	120 to 200
		Utica.	0-3		Fulton.	0-3
		Cynthiana.	40-90	(Lower Winchester.)	Point Pleasant. Greendale.	40-90
	Jessamine (Mohawkian.)	Lexington (Trenton.)	275		Perryville. Paris. Wilmore. Logana. Curdsville.	0-35 75 125 10 30
		High Bridge (Stones River.	400		Tyrone. Oregon. Campnelson.	90 25 285
	Canadian.				Not exposed in Kentucky.	

THE CHIEF DIVISIONS OF THE PALEOZOIC ROCKS OF KENTUCKY.

The superficial soils, clays, sands, and gravels of Kentucky are underlaid chiefly by Paleozoic rocks. Tertiary strata occur in the western part of the State, west of the Tennessee river. The Irvine clays, sands, and gravels of Powell, Estill, Clark, Madison, Garrard, and Lincoln counties have been referred provisionally to the Neocene, the upper half of the Tertiary. Similar local deposits of Tertiary age may occur elsewhere in the State, but in general it may be said that all of the more solid rocks of Kentucky, with their interbedded clays and shales, are of Paleozoic age. These Paleozoic rocks are classified under the following divisions, named in descending order:

PENNSYLVANIAN, including, in descending order:

2. The Coal Measures.
1. The Conglomerate Measures (or Pottsville).

MISSISSIPPIAN, or Lower Carboniferous, including, in descending order:

3. Shales, sandstones, and limestones corresponding to the Chester, etc.
2. Limestones, including St. Genevieve, St. Louis, etc.
1. The Waverly formation, using this name in the sense employed by former reports of the Ohio and Kentucky Surveys, and not as originally defined by Prof. C. Briggs, Jr. (First Annual Report of the Geological Survey of Ohio, 1838, page 80.)

DEVONIAN, including, in descending order:

2. The Devonian Black Shale, known on the eastern side of the Cincinnati geanticline as the Ohio shale, and on the western side as the New Albany shale. The United States Geological Survey has utilized the name Chattanooga shale for exposures of this shale in Eastern Kentucky, as far north as Clark county.

1. The Devonian limestones. In Ohio these limestones include, in descending order:
   - *c*. The Delaware limestone.
   - *b*. The Columbus limestone.
   - *a*. A comparatively unfossiliferous section of limestone, for which no distinctive name has been proposed as yet.

   For these three Devonian limestones of Ohio the name *Scioto* limestone would be very appropriate. Since the exact equivalency of the Devonian limestones of east-central Kentucky has not yet been determined, the name *Boyle* limestone will be used for the latter provisionally, because some of the thickest sections of Devonian limestone in Kentucky occur in Boyle county, and in the immediately adjacent counties.

SILURIAN, equivalent only to the Upper Silurian of former reports of the Kentucky Survey. Including, in descending order:

2. The Monroe formation, including the Greenfield limestone of Ohio and adjacent parts of Kentucky.
1. The Niagaran series of rocks, including, in descending order:
   - *b*. The Crab Orchard division of the Niagaran, consisting chiefly of clays; referred to the Niagara group in former reports of the Kentucky Survey.
   - *a*. The Brassfield limestone; referred to the Clinton group in former reports of the Kentucky Survey.

ORDOVICIAN, equivalent only to the Lower Silurian of former reports of the Kentucky Survey. Including, in descending order:

2. The Cincinnatian series of rocks; referred to the Hudson River group in former reports of the Kentucky Survey. These include:
   - *d*. The Richmond formation.
   - *c*. The Maysville formation, approximately equivalent to the Lorraine of New York.
   - *b*. The Eden formation, including, at the base, strata equivalent to the Utica of New York; and

- *a.* The Cynthiana formation, including the lower half of the Winchester limestone as originally defined by Marius R. Campbell.

1. The Jessamine series, corresponding approximately to the Mohawkian rocks of New York. This includes:
   - *b.* The Lexington formation, corresponding to the Trenton rocks of former reports of the Kentucky Survey; and
   - *a.* The High Bridge formation, belonging to the Stones River group of Tennessee, and including the rocks identified as Birdseye and Chazy in former reports of the Kentucky Survey.

In the preceding classification no attempt has been made to indicate in any manner the relative importance of the various divisions and subdivisions. The chief aim has been merely to indicate their relative order of succession.

If the superficial soils, clays, sands, and gravels of Kentucky were removed, the Pennsylvanian and Mississippian, collectively called the Carboniferous formations, would form by far the greater part of the surface of the State; according to estimate, about 70 per cent. Next in importance, as far as the area of exposure is concerned, would be the Ordovician, covering about 20 per cent. of the surface. Most restricted of all would be the areas of exposure of the Devonian and Silurian rocks, which, together, would form only between 3 and 4 per cent. of the total area of the State.

By far the greater part of the Devonian exposures of Kentucky consist of the Devonian black shale. The area of outcrop of the Devonian limestone is too narrow to be represented accurately on a map of ordinary size. On this account the United States Geological Survey has not attempted to distinguish between the Devonian limestone and the Silurian formations in Madison and adjacent counties (Richmond folio, No. 46, 1898), but has mapped them together under the name *Panolo* formation. The rocks identified with the Richmond formation in this Richmond folio include not only the Richmond formation as originally defined by E. O. Ulrich (including, in descending order, the Saluda, Versailles, Waynesville, and Arnheim beds), but also almost all of the Maysville formation, omitting only

the Mount Hope bed, at the base. The *Garrard* sandstone of the Richmond folio includes the Mount Hope bed at the base of the Maysville formation, and the upper division of the Eden beds. The Winchester limestone of the Richmond folio includes the Middle and Lower Eden beds and all of the Cynthiana formation.

In Ohio, the upper part of the Cynthiana division was called by Prof. Orton the Point Pleasant bed.

Ulrich, Bassler, and others have drawn the line of separation between the Cincinnatian and underlying series of rocks at the base of the Eden formation, beneath the Fulton layer with its Triarthrus becki fauna. In the classification here presented the line is placed at the base of the Cynthiana formation, in deference to the opinions of Mr. John M. Nickles, who recently has investigated the Cynthiana or Lower Winchester formation for the Kentucky Survey. (Bulletin No. 5.)

The Minor Subdivisions Adopted in this Report.

MISSISSIPPIAN.

In Ohio, the following subdivisions of the Mississippian have been adopted, named in descending order:

g. Maxville limestone,
f. Logan formation,
e. Black Hand formation,
d. Cuyahoga formation,
c. Sunbury shale,
b. Berea grit,
a. Bedford shale.

No attempt has been made as yet to trace any of these formations to any considerable distance southward from the Ohio river. It is not known whether the considerable body of soft clays at the base of the Waverly formation of Kentucky is exactly conterminous with the Bedford shale of Ohio. On this account the name Linietta clay was adopted, provisionally, from a

famous exposure at the Linietta Springs, southwest of Junction City, in Boyle county, Kentucky, before its identity with the New Providence shale of southern Indiana was ascertained.

Phosphatic nodules often are very abundant at the base of these clays and form a very characteristic horizon.

DEVONIAN.

In northern Ohio, the Devonian Black shale or Ohio shale has been divided, in descending order, into

c. The Cleveland shale,
b. The Chagrin formation, and
a. The Huron shale.

It is not known whether any of these subdivisions can be identified in Kentucky. Possibly the gigantic fish remains found in the Devonian Black shale east of Indian Fields, in Clark county, may eventually shed light on this question.

In Indiana, the Devonian limestones have been divided by Edward M. Kindle into three divisions, in descending order:

c. The Sellersburg beds,
b. The Jeffersonville beds, and
a. The Geneva limestone.

Of these, the Jeffersonville limestone corresponds approximately to the Columbus limestone of Ohio, while the Geneva limestone appears to occupy about the same position stratigraphically as the comparatively unfossiliferous section below the Columbus limestone, in Ohio.

The Sellersburg fauna has not been traced south of a railroad cut, a quarter of a mile south of Huber, sixteen miles south of the Ohio river at Louisville. In Ohio, the Delaware limestone has not been traced south of Columbus. The Devonian limestones of central Kentucky appear to be closely related to the Columbus limestone of Ohio and the Jeffersonville limestone of Indiana. In Indiana, the Geneva limestone appears to thin out southward before reaching the Ohio river. The Devonian limestones of Ohio are separated from the Devonian limestones of Kentucky by a broad area along the Ohio river, in which no Devonian limestones are known. Hence it is impossible to trace the divisions established in Ohio southward into Kentucky by stratigraphical means. Under these

circumstances, it, obviously, is impossible to determine whether any of the less fossiliferous beds at the base of the Devonian limestone section in Kentucky correspond to the comparatively unfossiliferous part at the base of the Devonian in Ohio, or not.

Several layers, apparently belonging to the Devonian limestone section of central Kentucky, deserve special consideration. One of these is a layer at the top of the section which frequently has a somewhat brecciated appearance. This appearance is believed to be due to pressure and to incipient yielding of rock without actual dislocations of the particles. Figures 2A and 2B on plate 8 give a very fair idea of the appearance of this rock when freshly broken. It is well exposed along the railroad cut, half a mile north of Junction City, in Boyle county, Kentucky, and it, therefore, has been called the *Duffin* rock or limestone.

Another interesting layer occurs at the base of the Devonian limestone section. It usually is strongly argillaceous, and frequently contains coarse sandy particles, some of which are black and nodular in character. This layer often is less than four inches in thickness, but frequently contains fish remains, including teeth and plates. In former reports of the Kentucky Survey, this layer was identified as Oriskany. It is well exposed along the railroad west of Preston, in Bath county; north of Berea, along the railroad, in Madison county; and at various localities near Indian Fields, in Clark county. The only available name for this rock appears to be *Kiddville* bed or layer, derived from a small hamlet, about a mile north of Indian Fields, near which a number of exposures occur, along the banks of Lulbegrud creek.

At several localities near Junction City, Crab Orchard, and elsewhere, the peculiar organism believed to be a worm boring, known as Taonurus caudagalli, is found in the lower, less fossiliferous part of the Devonian limestone section. It has not yet been determined whether this organism indicates any particular horizon in the Devonian limestone section. At present this appears to be the case, notwithstanding the fact that the same borings occur in great numbers also at various horizons in the Waverly section.

SILURIAN.

In Ohio, the Niagaran division of the Silurian has been divided into the following subdivisions, named in descending order:

f. Hillsboro sandstone,
e. Cedarville limestone,
d. Springfield limestone,
c. West Union limestone,
b. A formation identified with the Niagara shales of New York, usually with a persistent layer of limestone at the base, known as the Dayton limestone. Although these so-called shales consist of a considerable thickness of soft clays or clay shales in the southern part of the State, farther north and northwest, toward Xenia, Dayton, and Eaton, these clays are replaced by a much smaller section of thin limelimestones separated by partings of clay.
a. A limestone formation identified with the Clinton of New York.

In southern Indiana, the following subdivisions of the Niagaran are recognized:

e. Louisville limestone,
d. Waldron clay,
c. Laurel limestone,
b. Osgood clay, with some limestone,
a. A limestone formation identified with the Clinton of New York.

These subdivisions may be traced from southern Indiana southward as far as Raywick, in Marion county. No Niagaran exposures occur between Raywick and Stanford, in Lincoln county. Northeast of Stanford, along the eastern side of the Cincinnati geanticline in Kentucky, the Niagaran consists chiefly of limestones near the base, overlaid by a section of strata consisting chiefly of clay. The more continuous section of limestones at the base of the Niagaran have been identified in former reports of the Kentucky Survey with the Clinton of New York. The overlying clays are a southern continuation of the great mass of clays and clay shales in southern Ohio which have been

identified with the Niagara shales of New York, now known as the Rochester shales. The southern extension of these clays, in central Kentucky, were appropriately named the Crab Orchard shales, although this term was not defined with sufficient accuracy to determine what layer the author intended should form the base of these shales. As far as may be determined from the evidence at hand, these Crab Orchard clay shales correspond stratigraphically to the southern extension of the Osgood clay shales, on the western side of the Cincinnati geanticline.

For the more continuous limestone section, at the base of the Niagaran division of the Silurian, hitherto identified with the Clinton of New York, the name Brassfield limestone is proposed. The term Crab Orchard shales has been redefined, and, for purposes of more exact study, the following subdivisions have been proposed, named in descending order:

Crab Orchard division.....	Alger formation........	Estill clay.
		Waco limestone.
		Lulbegrud clay.
	Indian Fields formation	Oldham limestone.
		Plum creek clay.
		Brassfield limestone.

Where the Waco limestone horizon can not be distinguished the name *Flades* clay may be used so as to include both the Waco and Estill horizons.

Special consideration of the various divisions and subdivisions of the Niagaran of east-central Kentucky is deferred to a later part of this bulletin.

CINCINNATIAN.

The Cincinnatian formations of Ohio, Indiana, and Kentucky include great thicknesses of rock, shale, and clay, so that, in order to designate with greater exactness the location of individual layers or of the smaller sets of layers which for any reason may be of special interest, it has been found necessary to divide the groups already mentioned into still smaller subdivisions, named in the following list in descending order:

Richmond formation.........	Saluda bed.	
	Versailles bed.......	Whitewater division.
		Liberty division.
	Waynesville bed.	
Maysville formation..........	Arnheim bed.	
	Mount ~~Auburn bed.~~	
	Corryville bed.	
	Bellevue bed.	
	Fairmount bed, including Tate layer in upper half.	
	Mount Hope bed.	
Eden formation..............	Paint Lick bed, or Upper Eden.	
	Million bed.........	Middle Eden.
		Lower Eden.
	Fulton, or Triarthrus becki layer.	
Cynthiana formation.........	Point Pleasant bed.	
	Greendale bed.	

Of these formations, only the upper or Richmond formation will be of interest in connection with the present bulletin, since this is the formation upon which the Silurian formations rest.

THE CINCINNATI GEANTICLINE.

When rocks are traversed by long cracks and the strata on opposite sides of the crack are displaced by slipping, so that corresponding layers no longer are opposite to each other, they are said to be faulted, and the cracks are known as faults. Sometimes the displacement along these faults is of considerable dimensions, the layers on one side of the crack being found more than a thousand feet above or below the corresponding layers on the other side. Vertical displacements of these dimensions do not occur in central Kentucky, but several faults with displacements between 100 and 300 feet are known to exist, and some of these faults may be traced for a considerable distance across the State. One of these, known as the Kentucky River Fault, may be traced for a distance of forty miles a little south of west, across the southern ends of Clark and Jessamine counties. Another fault passes across the southern part of Garrard county, five miles south of the railroad passing through Paint Lick, and crosses Lincoln county south of Stanford and north of McKinney, in a direction also south of west. Other faults

follow very different directions. One of these, five miles east of Richmond, has a southeasterly direction.

In addition to faults, the rocks of the State are traversed also by various folds. Some of these are local. Others can be traced for long distances. Sometimes the folds and faults cross each other, so that the same area may be affected by more than one series of folds and faults.

Among the folds, one is preeminently dominant, since it affects the rocks of almost the entire State, extending northward into Ohio and Indiana, and southward to the southern boundaries of Tennessee. It is known as the Cincinnati geanticline. The crest or axis of this fold enters Kentucky from Ohio, east of Cincinnati, near the line between Pendleton and Bracken counties, and, traversing the State in a diagonal direction, enters Tennessee south of Burksville. From this crest or axis the rocks dip eastward, as far as the eastern margin of the State, and westward as far, at least, as Daviess, McLean, and Muhlenberg counties. On the eastern side of the crest, the rocks dip southeast toward Virginia. In the more northern parts of the State, west of the crest, the rocks dip westward, toward the southern part of Illinois. In the more southern parts of the State, possibly owing to a subsidiary line of folding whose axis extends in an east and west direction, the dips on the western side of the geanticline appear to swing around toward the northwest. Comparatively little accurate geological work has been done in this southwestern area as yet, but it is known that the western part of the State is traversed by some considerable faults, and probably by some folds.

A fold affecting rock over so wide a territory often is called a geanticline, in order to distinguish it from folds of much smaller dimensions, which receive the much more commonly used name of anticlines. In Ohio, this geanticline is known as the Cincinnati geanticline, Cincinnati being the most prominent city any where near the crest of the fold.

The crest or axis of the Cincinnati geanticline does not maintain the same general elevation along its entire length. Its greatest elevation, in Kentucky, appears to be south of Nicholasville, in Jessamine county. From this area the axis of the fold gradually sinks both toward the north and the south. It is estimated that from Lexington to the northeastern corner of

Pendleton county, on the Ohio river, the dip of the top of the Lexington limestone is almost 475 feet, an average dip of six feet per mile. From Nicholasville southward to Junction City, the dip is estimated at approximately 400 feet, a dip of almost seventeen feet per mile. From Junction City southward to the Cumberland river, the dip probably exceeds 250 feet, an average of about five feet per mile. Southward, from the Cumberland river toward Rutherford county, in central Tennessee, the continuation of the axis of the Cincinnati geanticline rises more than 700 feet.

Owing to the relatively low elevation of the axis of the Cincinnati geanticline in southern Kentucky, the fold has been regarded, at times, as made up of two domes, to the northern of which Prof. Arthur M. Miller has given the name Jessamine dome, while the southern culmination of the axis has been called the Rutherford dome. It should be remembered, however, that the structure in reality is that of a geanticline, and that the so-called domes are merely the areas of highest elevation along the axis of folding.

The dip, of course, is much greater down the sides of the geanticline than along its axis. Prof. Arthur M. Miller has shown that the elevation of the top of the Lexington limestone near Brannon Station, in Jessamine county, is 1,050 feet above sea level, while near Drennon Springs, toward the mouth of the Kentucky river, it is 430 feet, a drop of 620 feet in fifty miles, or a dip of 12.4 feet per mile. If these measurements had been made directly down the flanks of the anticline, a much greater dip would have been shown. It has been estimated, for instance, that from Lexington to Louisville, a distance of seventy miles, the dip is more than 1,500 feet, by far the greater part of this dip, 1,300 feet, occurring between Lawrenceburg and Louisville, a distance of fifty miles, or a dip of twenty-six feet per mile. In the same manner the dip from Lexington to Irvine, a distance of about thirty-six miles, has been estimated at fully 1,000 feet, a dip of twenty-eight feet per mile. These dips of twenty-six and twenty-eight feet per mile down the sides of the geanticline certainly are in great contrast with those along the crest of the fold, the dip from Lexington to the northeastern corner of Pendleton county being only six feet per mile, and that from Junction City to the Cumberland river,

five feet per mile. The considerable dip of seventeen feet per mile in the relatively short distance between Nicholasville and Junction City unquestionably has some connection with the line of faulting extending along the Kentucky river and with other minor faults not yet carefully investigated. The general effect of this faulting has been to place the strata south of Jessamine and Mercer counties at a considerably lower elevation than the corresponding strata north of the same. It probably is faulting rather than dip which accounts for the rapid sinking of the axis between Nicholasville and Junction City. The total lowering of the axis between Nicholasville and the Cumberland river is only nine feet per mile. Even the faults along the flanks of the geanticline appear to be of such a character as to leave the strata toward the crest of the geanticline at relatively higher elevations. Very few of these faults have been studied with any degree of care. In case of many of the minor folds not even the directions of the axes have been determined. Under these circumstances the more exact structure of the Cincinnati geanticline, in Kentucky, may be said to be still comparatively unknown.

Areas of Exposure of the Paleozoic Rocks of Kentucky.

If a considerable number of leaves of a book were moderately folded lengthwise, and then placed approximately horizontally upon a table, the axis of the fold would extend from the top to the bottom of the page, and from this axis the leaves would dip both to the right and the left. In this position, to an observer looking vertically downward, only the surface of the uppermost leaf would be visible. If, however, a number of incisions were made with a penknife, by roughly cutting through the uppermost leaves, the lower leaves would be exposed along the margins and lower parts of these cuts. In this state, the book would illustrate readily what would result if a series of approximately horizontal rock layers were gently folded and raised above the level of the sea. At first only the uppermost layers of rock would be exposed, but in the course of time, after streams and rivers had cut valleys into rocks, some of the underlying

layers also would become visible. The oldest rocks would be exposed along the bottom of the deepest valleys.

In the cases of streams cutting their channels transversely across the entire width of the fold, the lowest strata would be reached at the bottom of the channels in that part of their course which was directly beneath the crest of the fold. For instance, the lowest strata exposed in the State of Kentucky are found at the bottom of the gorge of the Kentucky river, near Camp Nelson, in the southern part of Jessamine county. The lowest strata exposed along the Licking river are exposed at the bottom of the channel somewhere between Falmouth and the mouth of North Fork. The lowest strata exposed along the Ohio river are seen east of Moscow. Both up and down stream from these localities, successively overlying beds are exposed at the river's edge. (See map opposite title page.)

If, now, with a sharp knife held horizontally, a considerable portion of the upper part of the fold formed by the leaves of the book were cut away, the lowest leaves would be exposed for considerable distances along the axis of the fold, directly beneath its former crest, and the overlying leaves would be found on each side of the fold, at successively greater distances from its axis. In this state, the book would readily illustrate what would result if the upper parts of a fold were removed by weathering, especially if the part remaining were reduced to a comparatively level, or only moderately undulating, plain. Those strata which belong lowest in the series would be exposed along that part of the surface which lay directly beneath the former crest of the fold,* and relatively overlying strata would come to the surface at approximately the same elevations, but at a greater distance from the former crest of the fold. The outcrops of the strata would form bands approximately parallel to the length of the fold, with the relatively lowest rocks forming the central band, and the overlying rocks occurring on both sides, but at successively greater distances from this band. In the case of folds whose flanks still show a considerable elevation above the surrounding country, the anticline structure may be recognized readily without the assistance of any considerable geological study. But in the case of folds which have been reduced by weathering to a comparatively level plain, the earliest

*See Plate B, Fig. 3. page 125.

clue to the anticline structure may be offered by the peculiar symmetrical arrangement of the strata, in long bands on opposite sides of the fold, the oldest strata along the middle of the fold, following the crest, the more recent strata on either side at successively greater distances from the axis.

If the original crest of the fold had varied considerably in altitude, rising at some points to considerable heights, and dipping thence for considerable distances toward both ends of the fold, the lines of outcrop of the various strata would have been more nearly oval or oblong. The oldest strata would be exposed in a central area underlying that part of the original crest of the fold which had attained the greatest elevation, and around this central area the relatively overlying beds would be arranged in successively more distant oval or oblong bands. This is the structure characterizing Kentucky and the adjacent parts of Ohio and Indiana.

The oldest rocks of the State, the High Bridge and Lexington formations, form a central area occupying the Bluegrass region of Kentucky, including the territory between Frankfort, Georgetown, Paris, Winchester, Nicholasville, Danville, Harrodsburg, and a considerable part of the immediately surrounding country. Surrounding this central area is the great band of Cincinnatian rocks, whose outer boundaries reach Bardstown and Lagrange, Kentucky; Madison, Versailles, Connersville, and Richmond, in Indiana; Eaton, Dayton, Xenia, Wilmington, and Sardinia, in Ohio; and Maysville, Owingsville, Richmond, and Stanford, in eastern Kentucky. It will be noticed that this band widens enormously on the northern and northwestern sides of the central area, occupied by the High Bridge and Lexington series. The general area of outcrop of these Ordovician strata, the High Bridge, Lexington, and Cincinnatian rocks, is shown on the map facing the title page of this bulletin. Here the area left in white represents the area of outcrop of the Ordovician strata of Ohio, Indiana, and the north-central part of Kentucky, with the exception of that small part of the map which represents the country south of Chicago, Lebanon, and Stanford, where the Ordovician rocks frequently are overlaid directly by Devonian strata. In the areas covered by the small dots, Silurian rocks occur, either exposed at the surface, or covered by Devonian and later formed strata. The general direc-

tion followed by the axis of the Cincinnati geanticline in Kentucky is indicated by the legend printed across the lower part of the map. The dotted line, extending from that point on the map marked Chicago to Frankfort, Boyd, Paris, Lancaster, and Stanford, is not intended to limit the axis of the fold, but to indicate that part of the State in which it is believed that the Devonian formerly rested directly upon the Ordovician, the Niagran strata being absent. Since the delimitation of this area, north of Chicago, Lebanon, and Stanford, is merely theoretical and not based upon a sufficient number of verified data, this feature of the map is offered rather as an interesting suggestion, than as a well established fact.

In Kentucky, the Silurian formations form a narrow band bordering the exterior edge of the Ordovician area. From Stanford this band extends northward to the Ohio river at a point fully ten miles east of Maysville; thence it continues into Ohio to a point about fifteen miles west of Columbus, widening rapidly north of the Ohio river. North of Eaton, Dayton, and the point west of Columbus, the Silurian covers almost the entire western section of the State, as far north as Toledo and Sandusky, with the exception of the extreme northwestern corner of the State, and several small areas east of Bellefontaine. Westward, the Silurian may be traced across the northern part of Indiana to Illinois and Wisconsin. Farther south, in Indiana, the western line of exposure extends from Peru to Kokomo, Noblesville, Rushville, Greensburg, and Madison. It crosses the Ohio river at Louisville, and from this point Silurian strata may be traced as far south as Raywick, west of Lebanon, Kentucky. Between the exposures several miles east of Raywick and those three miles south of Stanford, the Silurian formations are absent, the Devonian strata, when present, resting directly upon the Ordovician.

The Devonian formations, in Kentucky, form narrow bands similar to those of the Silurian just described, but across the south-central part of the State, between Raywick, Lebanon, and Stanford, the line of outcrop practically is continuous. From Stanford, the band of Devonian rocks extends northward to Vanceburg, Kentucky, to Columbus and Bucyrus, Ohio, reaching Lake Erie at Huron and Vermillion. Throughout this entire length it remains a remarkably narrow and characteristic band,

easily recognized, and has formed one of the most valuable horizon markers for the geologist.

North of Raywick, the Devonian formations may be traced to Louisville, and thence to Columbus, Indianapolis, and Lafayette, to Rensselaer, in the northwestern part of the State of Indiana. Here again it forms a very characteristic band, although broader than in the State of Ohio.

At distances still more remote from the area of outcrop of Ordovician strata occur first the Mississippian strata, and then the Pennsylvanian formations, or Coal Measures.

The special field of investigation covered, in a preliminary manner, by this bulletin, is the distribution and stratigraphical arrangement of the Silurian clays along the eastern side of the Cincinnati geanticline, in Kentucky. Since it was impossible, in the brief time devoted to field work, to examine thoroughly all parts of this territory, attention was confined chiefly to that part of the band of Silurian rocks lying between Stanford and Owingsville, and more especially to that part of this area lying between Moberly, Panola, Irvine, Clay City, and Indian Fields. The extension of the stratigraphy worked out in this more limited area to the entire area between Stanford and Owingsville has been attended with some difficulties which have not been fully conquered. The solution of the various problems involved must depend upon future field work. Advantage was taken, however, of the numerous notes accumulating during this preliminary survey, to give all information available regarding the limestones, accompanying the Silurian clays, the Devonian limestones overlying the Silurian formations, and such other information as was thought might prove of interest at this early stage of progress of the Survey.

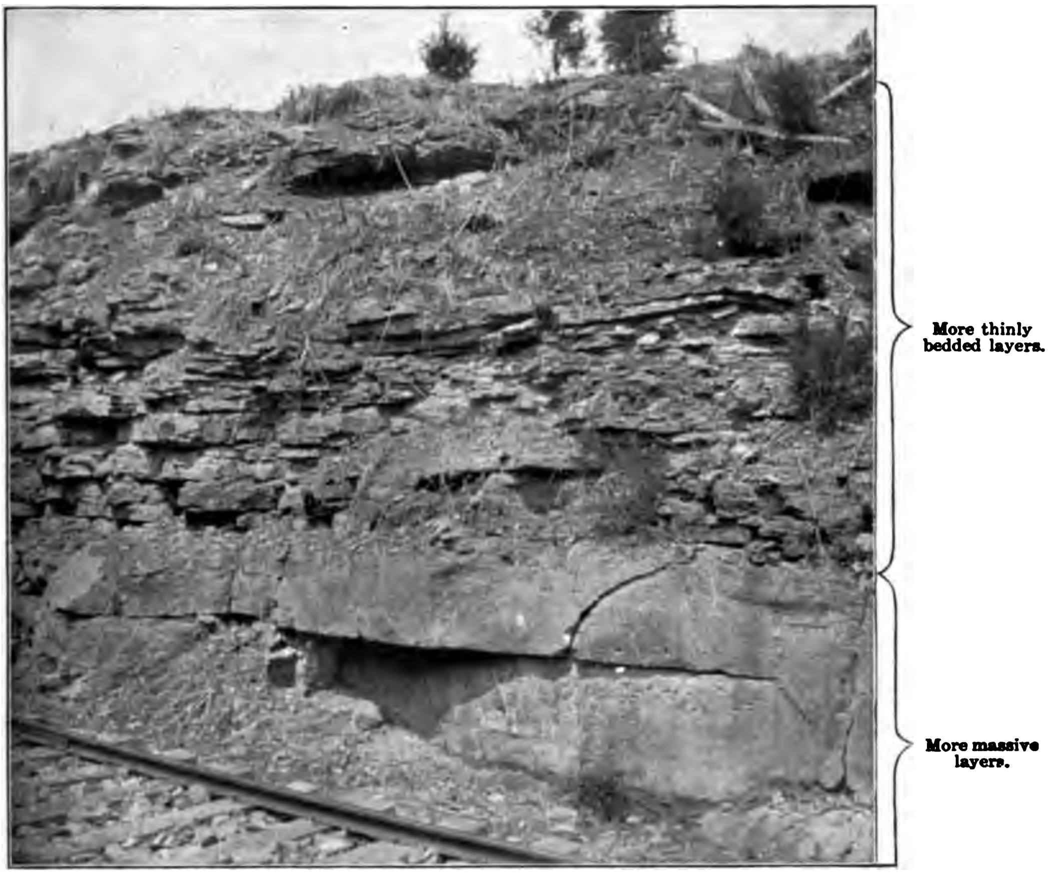


Fig. 1. Brassfield or Clinton Bed, between Brassfield and Panola, on the Louisville and Atlantic R. R. Near the eastern end of the type section.

The Classification of Silurian Rocks of East-Central Kentucky.

TABLE OF FORMATIONS.

Crab Orchard division of Silurian.....	Alger formation..............	Estill clay.
		Waco limestone.
		Lulbegrud clay.
	Indian Fields formation......	Oldham limestone.
		Plum creek clay.
	Brassfield formation..........	Brassfield limestone.

BRASSFIELD LIMESTONE.

The typical exposure of the Brassfield limestone occurs along the Louisville and Atlantic Railroad, between Brassfield and Panola, in Madison county. Here the lower part of the limestone is exposed best near Panola, while the upper part is seen nearer Brassfield. An equally good exposure is found about a mile and a half northwest of Indian Fields, west of Howard creek, along the Lexington and Eastern Railroad, in Clark county.

The lower part of the Brassfield limestone usually consists of one or several rather thick and massive appearing layers, while the middle and upper part consist of more numerous, thinner-bedded layers; toward the top of the section these limestones often are interbedded with thin layers of clay. (See Fig. 1.)

The massive layers, at the base, usually are unfossiliferous, even on close examination. They do not weather to as deep a rusty-yellowish-brown as the thinner layers of the Brassfield limestone. Frequently they have a more argillaceous appearance than the thinner layers, and their color, when freshly exposed, is more bluish. On this account there was at first a disposition to separate these more massive layers at the base of the Brassfield section from the more thinly bedded limestones above, but further observations have not proven that they form a distinct series. It has been noticed that in some areas the total thickness of these massive layers seems to vary consider-

ably, while the thickness of the entire Brassfield section, in the same area, is fairly constant. In most cases only the lower part of the Brassfield limestone has a massive appearance, while in others almost the entire section has this massive character. From this the conclusion has been drawn that the conditions favoring the formation of massive beds were quite general at the beginning of the period of deposition of the Brassfield limestone, but that the changes favoring the formation of thinner beds entered different parts of the field at different times, so that massive beds continued to be formed at some localities, while thinner layers already were being formed at others.

Between Brassfield and Panola, the total thickness of the massive layers is six feet. Northwest of Indian Fields, it is seven feet. Southeast of Bobtown, it is eight feet. Near Hammack, the massive layer varies between eight and nine feet, and forms practically the entire Brassfield section. East of College Hill, on the contrary, the massive layer is only sixteen inches thick, and the overlying part is well bedded. West of Crab Orchard, on the eastern side of Cedar creek, along the pike to Stanford, the massive layers have a thickness of four feet four inches; the overlying part, three feet four inches thick, is separable into a greater number of layers, but evidently corresponds to the upper part of the massive section as exposed at Hammack, or at the Anderson locality, three and a half miles southeast of Lancaster. In the same manner, at Crab Orchard, a mile and a half west of the railroad station, along the county road, the massive limestone has a thickness of only two and one-half feet; a mile and a half farther west, along the same road, its thickness is two feet; while between these localities, on the western side of the eastern fork of Cedar creek, the Brassfield rock has a fairly massive appearance for a total thickness of eight and one-half feet above the base. About four miles north of Berea, half a mile south of Whites Station, the massive layer at the base of the Brassfield limestone has a thickness of two feet, but the lower part of the immediately overlying thinner-bedded layers evidently corresponds stratigraphically to the upper part of the more massive layers, as exposed southeast of Bobtown.

As far as may be judged from the massive appearance of these layers where they project from the sides of ravines, these

massive layers withstand the action of weathering well, and could be employed locally for building rock. However, owing to the moderate thickness of even the thickest exposures, it would not pay to open extended quarries in this rock.

The overlying parts of the Brassfield limestone are too thin-bedded and irregular to be of value for any purpose except crushed rock. In the lower part of this thin-bedded section, the limestone layers are likely to be separated by very thin layers of clay. In the upper part of the Brassfield section, these layers of clay are likely to be thicker, but not sufficiently to predominate over the limestones. Farther northward, from Montgomery county, in Kentucky, to Highland county, in Ohio, the relative quantity of clay in the upper part of the Brassfield section increases. Northwest of Highland county, however, clay occurs only at the very top of the Brassfield section, and at many localities is absent. It is the upper, thinner-bedded part of the Brassfield limestone which is fossiliferous. Most of the fossils occur near the top of the section.

The greatest thickness of the Brassfield limestone, in the area under investigation, was recorded from the type locality, between Brassfield and Panola (from eighteen to nineteen and one-half feet), and from the railroad cut a mile and a half northwest of Indian Fields (about nineteen feet). About four and a half miles northeast of Berea and a mile southeast of Bobtown, at the northern end of the Jackson hollow, its thickness is seventeen feet. About three and a half miles south of west from Clay City, north of Snow Creek church, the Brassfield limestone measures nearly sixteen feet. However, in by fa: the greater part of the area between Owingsville and Stanford, the thickness of the Brassfield limestone does not exceed thirteen feet, and often is less than this amount.

The data so far accumulated do not warrant any definite statements as to the relation between the variation in thickness of the Brassfield limestone and the distance of the various exposures from the crest of the Cincinnati geanticline. However, the following variation in thickness was noticed. Southeast of Bobtown the Brassfield limestone is seventeen feet thick. Southeast of Brassfield, it is nineteen feet thick. West of the first mentioned locality, the sections examined so far measure thirteen feet or less, and north of the second locality the record-

ed thicknesses do not exceed thirteen or fourteen feet. These facts suggest that in this area the Brassfield limestone possibly becomes thinner toward the northwest. Several other, isolated, observations favor this view. One of these is the small thickness of the Brassfield section (nine feet) at a locality three and a half miles southeast of Lancaster, on the road to Hammack. Another, is the small thickness (ten feet) seven miles southwest of Indian Fields, and a mile north of Merritt, at the Simpson Brock locality. However, the considerable thickness (sixteen to nineteen feet) of the Brassfield limestone along the long line between Plum creek, southwest of Clay City, and the exposures along the railroad northwest of Indian Fields, suggest that possibly any attempt to generalize regarding the relations between the variations in thickness of the Brassfield limestone and the relative distance of the various exposures from the crest of the Cincinnati geanticline is premature. A great part of these variations may be quite irregular and local.

FAUNA OF THE BRASSFIELD LIMESTONE.

The Brassfield limestone of east-central Kentucky contains the southern extension of the fauna characteristic of the limestone section which in Ohio and Indiana has been identified as Clinton.

Along the railroad between Brassfield and Panola the following species were found in the upper part of the Brassfield limestone, between two and five feet below the *Whitfieldella* horizon, which forms the upper boundary of the Brassfield section:

Calymmene vogdesi,
Cyclonema daytonensis,
Rhynchotrema scobina,
Leptaena rhomboidalis,
Plectambonites transversalis,
Platystrophia reversata,
Dalmanella elegantula,
Rhinopora frondosa,
Aspidopora parmula,
Cyathophyllum calyculum.

Almost directly east of the home of James F. Harris, north of Irvine, where the road crosses White Oak creek, almost at the level of the creek, the following species occur, just beneath the *Whitfieldella* horizon:

Calymmene niagarensis,
Cyclonema daytonensis,
Rhynchotrema scobina,
Leptaena rhomboidalis,
Plectambonites transversalis,
Dalmanella elegantula,
Orthis flabellites,
Rhinopora frondosa,
Phylloporina angulata,
Cyathophyllum calyculum.

Nearly a mile and a half northwest of Indian Fields, along the railroad, in a railroad cut, the following species were found between one and five feet below the Plum creek clay. The layer immediately beneath this clay contains large crinoid beads and a few specimens of the *Whitfieldella* characteristic of this horizon.

Calymmene vogdesi,
Cyclonema daytonensis,
Rhynchotrema scobina,
Triplecia ortoni,
Orthothetes fissiplicata,
Leptaena rhomboidalis,
Dalmanella elegantula,
Phylloporina angulata,
Rhinopora frondosa,
Phaenopora expansa,
Zaphrentis daytonensis,
Cyathophyllum calyculum.

Along the country road south of the railroad, two miles west of Crab Orchard, the following species were seen in the upper part of the Brassfield bed, below the *Whitfieldella* horizon:

Orthis flabellites,
Platystrophia daytonensis,
Leptaena rhomboidalis,
Zaphrentis daytonensis,
Cyathophyllum calyculum.

At the Neal Creek church, three miles south of Stanford, the following species occur in the upper part of the Brassfield limestone:

> *Orthis flabellites,*
> *Dalmanella elegantula,*
> *Strophonella daytonensis,*
> *Pachydictya bifurcata,*
> *Halysites catenulatus,*
> *Favosites niagarensis,*
> *Cyathophyllum calyculum.*

In the railroad cut almost three miles north of Berea, immediately below the layer with large crinoid beads and occasional specimens of *Whitfieldella,* the following species occur:

> *Orthothetes cf. tenuis,*
> *Platystrophia daytonensis,*
> *Heliolites subtubulata,*
> *Cyathophyllum calyculum.*

Heliolites subtubulata occurs in the Brassfield limestone also along the creek, southwest of the railroad station at Panola.

East of Moberly, at Elliston, the top of the Brassfield limestone section contains:

> *Orthis flabellites,*
> *Leptaena rhomboidalis,*
> *Cyathophyllum calyculum.*

South of Indian Fields, at Abbott's Mill, the upper part of the Brassfield section contains:

> *Rhinopora frondosa,*
> *Zaphrentis daytonensis,*
> *Cyathophyllum calyculum.*

In the lower part of this section, the following species are found:

> *Cyclonema daytonensis,*
> *Leptaena rhomboidalis,*
> *Clathropora frondosa.*

About seven miles southwest of Indian Fields, and a mile north of the old Simpson Brock place, the following species

occur in the upper part of the Brassfield limestone, just below the *Whitfieldella* layer:

Dalmanella elegantula,
Rhinopora frondosa,
Ptychophyllum ipomea,
Cyathophyllum calyculum.

A much greater fauna has been discovered in the northern extension of the Brassfield limestone, in Ohio and Indiana. Among the trilobites this fauna includes:

Illaenus daytonensis,
Illaenus ambiguus,
Illaenus madisonianus-elongatus,
Illaenus madisonianus-depressus,
Proetus determinatus,
Cyphaspis clintonensis,
Lichas (Platynotus) clintonensis,
Acidaspis (Odontopleura) ortoni,
Encrinurus ornatus,
Calymmene vogdesi,
Calymmene niagarensis,
Ceraurus (Pseudosphaerexochus) clintonensis.
Deiphon pisum,
Phacops pulchellus,
Dalmanites (Odontochile) werthneri.

Among the brachiopoda, this fauna includes:

Craniella clintonensis,
Plectambonites transversalis-elegantulus,
Plectambonites prolongatus,
Leptaena rhomboidalis,
Strophonella daytonensis,
Strophonella hanoverensis,
Orthothetes daytonensis (=O. tenuis, Foerste),
Orthis flabellites,
Hebertella fausta,
Hebertella daytonensis,
Platystrophia reversata,
Platystrophia daytonensis,
Dalmanella elegantula,

Rhipidomella hybrida,
Triplecia ortoni,
Whitfieldella sp.,
Atrypa marginalis,
Camarotoechia scobina,
Camarotoechia convexa,
Parastrophia sparsiplicata,
Stricklandinia triplesiana.

Among the bryozoans, the following are seen:

Homotrypa confluens,
Aspidopora parmula,
Lioclemella ohioensis,
Callopora magnopora,
Phylloporina angulata,
Hemitrypa ulrichi,

Ptilodictya whitfieldi (= *Pt. expansa,* Hall; 12th Rep. Indiana Geol. Survey, plate 12, Figs. 2, 3; published in 1883; also *Pt. expansa,* Foerste, Bulletin, Lab. Denison Univ., Vol. II, plate 15, Fig. 5, published in 1888. Not *Paenopora expansa,* Hall and Whitfield, Ohio Pal., Vol. II, plate 5, Fig. 1, published in 1875.)

Ptilodictya americana (= *Pt. expansa,* Foerste, in part; Bulletin, Lab. Denison Univ., Vol. II, page 156).
Clathropora frondosa,
Clathropora clintonensis,
Phaenopora expansa (= *Ptilodictya platyphylla,* James; *Pt. bipunctata,* Hall),
Phaenopora fimbriata,
Phaenopora magna,
Phaenopora welshi (= *Ph. multifida,* Hall),
Pachydicta bifurcata,
Pachydictya instabilis,
Pachydictya crassa,
Pachydictya emaciata,
Trigonodictya eatonensis,
Rhinopora frondosa.

These lists are sufficient to indicate the Silurian character of the fauna found in the Brassfield limestone of east-central Kentucky and in the northern extension of this limestone in

Ohio and Indiana. Compared with the Clinton of New York, the absence of the following brachiopoda is noteworthy:

Stropheodonta profunda,
Strophonella (?) patenta,
Orthothetes subplanus,
Pentamerus oblongus,
Barrandella fornicata,
Rhynchonella robusta,
Atrypa reticularis,
Spirifer radiatus,
Spirifer niagarensis,
Spirifer crispus-corallinensis,
Hyatella congesta,
Anoplotheca hemispherica,
Anoplotheca plicatula.

Among these species, *Pentamerus oblongus* makes its first appearance in the Dayton limestone, which immediately overlies the northern extension of the Brassfield limestone in Ohio; *Atrypa reticularis, Spirifer radiatus,* and *Spirifer niagarensis* are seen, in Indiana, in the limestones which overlie the clay shales, there known as the Osgood clay. Although these limestone layers have been included in the Osgood formation, on account of an overlying, but much thinner, layer of clay occurring in some parts of that State, they might with equal propriety be considered as forming the base of the Laurel limestone section.

The identification of the Brassfield limestone of Kentucky, and of its northern extension in Ohio and Indiana, in former years, with the Clinton limestone of New York, rests rather upon a somewhat similar facies of the two faunas, and upon the general absence of the more typical species of the Rochester shale fauna of New York in these limestones at the base of the Silurian in Ohio, Indiana, and Kentucky, than upon the presence of any considerable number of species common to both areas. On closer inspection, the fauna of the Brassfield limestone of Ohio, Indiana, and Kentucky appears to differ sufficiently from the fauna of the Clinton limestone of New York to warrant the assumption of the presence of some sort of barrier between these two areas.

Whitfieldella Horizon.

The fossils listed in the preceding section occur chiefly in the upper part of the Brassfield section, consisting of rather thin layers of limestone interbedded with a little clay. Immediately above this section, there is a thicker and more sandy appearing layer, usually about one foot thick, but occasionally equalling two feet. In this layer large crinoid beads, often half an inch in diameter, are common. *Whitfieldella subquadrata* (Plate 1, Fig. 3) also occurs in considerable abundance at some localities, and has a wide geographical distribution at this horizon in eastern Kentucky. When these species are not intermingled, the *Whitfieldella* usually occurs in the upper part of the sandy appearing layer, and the large crinoid beads are found either in the lower part of this layer or at the top of the immediately underlying rock.

Owing to the porous nature of the sandy appearing layer, the specimens of *Whitfieldella* occur chiefly as casts, the shells having been dissolved and carried away in solution by percolating waters, leaving the impressions of the exterior form of the shell upon the surrounding rock, and often preserving the casts of the interiors of the shells in a remarkable manner. The part usually noticed is that near the hinge line, because here the shell was thickest, and the removal of the shell material left the greatest cavities, exposing beautifully the casts of the interior of the shell, especially of the deep muscular scar in the pedicle valve, and of the strong transverse ovarian ridges on each side. This portion of the cast of the interior of *Whitfieldella subquadrata* frequently appears to have been identified as *Atrypa reticularis*, a fact which it is necessary to keep in mind in reading the literature of this part of the Silurian geology of Kentucky. While such an identification would be inexcusable at the present day, it should be remembered that some valuable work was done in former years by men who did not have the advantages in scientific training which now can be secured by all. As a matter of fact, *Atrypa reticularis* does not occur in the *Whitfieldella* layer.

Associated with the large crinoid beads and the *Whitfieldella subquadrata*, is a small species of cyathophylloid coral, usu-

ally less than an inch in length, which has not been carefully studied, but which passes in these notes under the name *Cyathophyllum calyculum*. A species of *Orthothetes* occurs occasionally.

The most northern locality at which *Whitfieldella subquadrata* has been found in abundance is west of Slate creek, east of Spencer, in Montgomery ounty. The most northern locality at which it has been identified with certainty is along the railroad, about a mile west of Preston, in the southern part of Bath county. Southward it may be recognized, still at the same horizon, on Fishing creek, directly west of Somerset, and along the Cumberland river, in Pulaski and Wayne counties. Stratigraphically, therefore, the *Whitfieldella subquadrata* layer is remarkably persistent. This makes it valuable as an horizon marker, especially in exposures of limited vertical extent. For instance, at the point a mile north of Irvine, where the road passing Estill Springs crosses White Oak creek, there is a small exposure, only four or five feet high, along the water's edge, on the west side of the creek. One of the layers shows the sandy appearance and contains the large crinoid beads and the *Whitfieldella*. This at once indicates that the immediately underlying rock belongs to the Brassfield limestone section, a fact corroborated by the discovery of fossils characteristic of that horizon in this rock at the same locality.

The most interesting feature of the *Whitfieldella subquadrata* horizon, however, is not its extended distribution or its value as an horizon marker, but the evidence which it presents of some geographical change preceding its deposition. The coarser, sandy, more porous structure of the rock suggest that its materials were swept together by stronger currents than those which brought in the sediments forming the underlying limestones. This evidence is corroborated by the presence of coarse bedding, and occasionally even of cross bedding, at this horizon. The large crinoid beads have the appearance of having been swept together by currents which caused the disintegration of the less compact structure of other remains of animal life. The coarse *Whitfieldella* is one of the few fossils at all common at this horizon. Other remains frequently show considerable rounding at the edges, suggesting that they were rolled by currents of water before reaching their final resting place.

The absence of a considerable part of the fauna characteristic of the Brassfield limestone in this *Whitfieldella* layer, and the sudden introduction of the *Whitfieldella subquadrata* suggests the lapse of a sufficient interval of time to have permitted a shifting of faunas. The *Whitfieldella* horizon probably heralds the introduction of a new fauna, and for this reason it is used in discriminating the overlying beds from the Brassfield limestone. At present, however, comparatively little is known of the faunas of these immediately overlying limestones or of the Oldham bed.

Rose Run Iron Ore.

About a mile west of Preston, along the railroad, a short distance east of the home of William Johnson, the *Whitfieldella* layer is exposed. The top of the Silurian formations is seen farther east, in a railroad cut. The following section is seen, in descending order:

Devonian Black shale.		
Devonian limestone	11 ft.	8 in.
Alger clay	60 ft.	
Oldham limestone and clay	5 ft.	
Plum creek clay	7 ft.	6 in.
Light brown limestone		4 in.
Clay		8 in.
Ferruginous limestone, with large crinoid beads in lower part	1 ft.	
Limestone, containing large crinoid beads and one good *Whitfieldella subquadrata*		5 in.
Clay, top of Brassfield section		7 in.
Limestone		4 in.
Clay		7 in.
Ferruginous limestone	1 ft.	
Remainder of Brassfield section not measured.		

About two miles southwest of Preston, along the road leading to Howard Mills, east of a crossing of a small branch emptying into Slate creek, the following exposure is seen, in descending order:

Cherty Devonian limestone.		
Alger clay	60 ft.	
Oldham limestone and clay, limestones at the top thinner and separated by more clay	9 ft.	6 in.
Plum creek clay	5 ft.	6 in.
Wave-marked limestone		4 in.
Clay		4 in.
Limestone, strongly ferruginous, containing one *Whitfieldella subquadrata*	1 ft.	
Limestone, with large crinoid beads		2 in.
Clay chiefly, top of Brassfield section	2 ft.	
Limestone, strongly wave-marked, with large crinoid beads		9 in.
Chiefly clay	2 ft.	3 in.
Limestone, layers of irregular thickness	1 ft.	2 in.
Limestone, hard layer		10 in.
Clay		6 in.
Massive limestone forming the remainder of the Brassfield section	10 ft.	

About four miles east of Owingsville, on the northern side of Rose Run, there are wide areas in which a hematitic iron ore is quarried. At this locality the following exposures are seen, in descending order:

Oldham limestone and clay, lower part of section	5 ft.	
Plum creek clay	8 ft.	
Limestone, wave-marked		4 in.
Blue hydrated iron ore		5 in.
Red hematitic iron ore	3 ft.	
Brown limestone, top of Brassfield section		5 in.
Clay		4 in.
Limestone with large crinoid beads		6 in.
Remainder of Brassfield section not measured.		

From these sections it may be seen that the horizon of the valuable iron ore deposits of this part of Kentucky is below that of the Plum creek clay, and occupies about the same level as the *Whitfieldella subquadrata* layer. This does not mean that none of the layers of limestone immediately underlying or overlying the *Whitfieldella* layer may be ferruginous, but that the *Whitfieldella* layer is the horizon of the richest ores, and is the only layer of commercial value.

All of the valuable deposits of this hematitic iron ore occur in the immediate vicinity of Owingsville, chiefly along Rose Run. The horizon, however, may be traced farther northward.

At the mill on Fox creek, two miles below Farmville, the following section is exposed, in descending order:

Clay with a little thin-bedded limestone, base of Plum creek clay section	2 ft.	
Light brown limestone		4 in.
Red ferruginous limestone	1 ft.	4 in.
Limestone full of large crinoid beads	1 ft.	
Blue clay, top of Brassfield section	1 ft.	6 in.
Limestone, strongly wave-marked		10 in.
Limestone, thin bedded		8 in.
Clay	1 ft.	4 in.
Limestone, hard layer		6 in.
Clay	1 ft.	6 in.
Clayey rock		6 in.
Remainder of Brassfield section not exposed.		

Along the railroad, one mile north of Hillsboro, the following section is exposed, in descending order:

Oldham limestone and clay, 5 ft. 4 in. thick, consisting of the following members:		
Limestone		8 in.
Clay		4 in.
Limestone, slightly ferruginous	1 ft.	7 in.
Clay		4 in.
Limestone		4 in.
Clay	1 ft.	6 in.
Several limestone layers		6 in.
Plum creek section, chiefly clay, 6 ft. 6 in. thick, consisting of the following members:		
Clay		10 in.
Limestone lenses		1 in.
Clay	3 ft.	
Limestone, thin layers		2 in.
Clay		9 in.
Limestone, light brown, thin		4 in.
Clay		4 in.
Limestone, brown tinged with red		2 in.
Limestone, red purple		2 in.
Limestone, strongly ferruginous, dark layer	1 ft.	3 in.
Limestone, not ferruginous, somewhat cross-bedded in places		6 in.
Clay, top of Brassfield section	1 ft.	7 in.
Limestone, wave-marked, often absent along the troughs, but remaining along the ridges as lenses, when seen in cross section, with large crinoid beads		4 in.

Clay	1 ft.	
Limestone, wave-marked, with large crinoid beads		6 in.
Chiefly clay, with a little thin limestone at several levels	4 ft.	2 in.
Limestone, hard		6 in.
Clay		4 in.
Chiefly light brown or blue limestone	2 ft.	2 in.
Blue clay and limestone, poorly exposed	3 ft.	
Limestone		6 in.
Clay		10 in.
Solid massive limestone with chert, base of Brassfield section	5 ft.	6 in.
Belfast layer	3 ft.	

A number of instructive sections occur in Adams county, Ohio, in the neighborhood of West Union, and between West Union and Dunbarton. One of these sections is located along the ravine of the first stream crossing the road east of Sprow's bridge, northeast of Duncansville, not far east of the pike from West Union to Peebles. The section is north of the road, back in the woods, up the gully toward the northeast. Here the following rocks are shown, in descending order:

Limestone, massive, possibly the equivalent of the Dayton limestone	3 ft.	
Limestone and clay, corresponding approximately to the Plum creek horizon; *Atrypa reticularis* occurs 1 ft. above the base	7 ft.	
Purple ferruginous limestone with large crinoid beads.		5 in.
Limestone with large crinoid beads		4 in.
Clay		6 in.
Limestone, massive, crinoidal		6 in.
Clay with a little thin limestone near middle		10 in.
Whitfieldella quadrangularis layer		6 in.
Chiefly clay, top of Brassfield section	1 ft.	3 in.
Limestone, wave-marked		4 in.
Interval not recorded	19 ft.	
Limestone, massive, lower part cherty	2 ft.	8 in.
Limestone, white, forming small fall	1 ft.	
Limestone, very cherty	6 ft.	
Limestone, thin bedded, base of Brassfield section	6 ft.	
Clay rock with calcite	2 ft.	
Belfast bed	4 ft.	

Another section occurs north of the Whipporwill church, along the pike from West Union to Peebles, about three miles

northeast of West Union. Here the following rocks are seen, in descending order:

Limestone, massive, possibly equivalent to the Dayton limestone.		
From the top of this massive limestone to the ferruginous layer the interval, possible equivalent to the Plum creek horizon, is..............................	7 ft.	
Oolitic ferruginous layer, containing *Pleurotomaria inexpectans*, and other fossils.		
From the top of the ferruginous layer to the top of that next mentioned the interval is..............	3 ft.	8 in.
Limestone, massive, crinoidal, with *Atrypa reticularis* and other fossils..................................	1 ft.	6 in.
Limestone, wave-marked, with many large crinoid beads.		
From the top of the wave-marked layer to the base of the cherty layer the interval is......................	28 ft.	
Limestone, thin bedded, forming base of Brassfield section, including *Hebertella fausta*....................	7 ft.	
Belfast bed.		

The third section of importance in this connection is exposed southeast of West Union, along the road to Beasley Fork. The section begins at West Union and is described in descending order:

Alger clay...	148 ft.	
Limestone, massive, in 6-inch layers, probably equivalent to Dayton limestone, exposed near home of John Morrison	4 ft.	6 in.
Limestone, poor, thin bedded.........................	1 ft.	6 in.
Clay, with thin limestone layers......................	1 ft.	2 in.
Limestone, wave-marked		3 in.
Clay		8 in.
Limestone		3 in.
Clay		3 in.
Limestone, with large wave marks..................		6 in.
Limestone		6 in.
Clay, with a little thin limestone....................	1 ft.	6 in.
Limestone with large wave marks and containing large crinoid beads...............................		6 in.
From base of last layer to base of cherty limestone, including almost all of the Brassfield section, the interval is...	26 ft.	
Limestone	2 ft.	
Limestone, massive, called iron ledge by natives......	1 ft.	2 in.

Belfast bed, near home of Matilda F. Blake..........	4 ft.	
Saluda bed	24 ft.	
Interval	26 ft.	
Strongly wave-marked limestone, near home of Simon Nixon		6 in.
Interval	147 ft.	
Leptaena rhomboidalis horizon in Arnheim bed.		

A comparison of these three sections with those in Kentucky suggests that possibly the Oldham limestone section of east-central Kentucky is represented in Ohio by the Dayton limestone. North of Hillsboro, Kentucky, the Plum creek clay section appears to contain more and more limestone. In this form it may be traced into the central part of Adams county. Farther north this Plum creek section either disappears or becomes a part of the Dayton limestone section. The ferruginous horizon appears to occur at a distinctly higher level in Adams county, Ohio, than east of Owingsville, Kentucky. In Adams county it is separated from the *Whitfieldella quadrangularis* horizon by an interval of at least two feet. Farther northward the Dayton lime usually rests directly upon the Brassfield layer or is separated only by the ferruginous layer.

In Ohio, there evidently is an unconformity between the top of the Brassfield limestone section and the base of the Dayton limestone. This is indicated by the large pebbles found in the ferruginous and wave-marked rock immediately overlying the Brassfield section south of the Elk Run bridge, two miles east of Belfast, in the southeastern part of Highland county, in Ohio. Here many of the pebbles are four to eight inches long, and some are even twelve inches in length. Pebbles, three inches long, occur at the same horizon along the creek immediately northwest of Belfast. Pebbles occur also near the middle, and at several points above the middle of the Brassfield bed at Belfast, and near Sharpsville, also in Highland county. The interpretation of these features has not yet been carefully worked out, but the evidence is in favor of the presence of a number of strata between the Dayton limestone and the Brassfield limestone section, in southern Ohio, and northern Kentucky, which do not appear to be represented farther north, in Ohio and Indiana.

Moreover, in both States, Kentucky and Ohio, the ferruginous oolitic rock appears to be associated with evidences of

stronger current action, such as a sandy appearing texture, cross bedding, wave marks, and, locally, with pebbles, features which characterize the shallower seas. This arouses the inquiry, whether the segregation of the iron in these oolitic beds may not have taken place largely at the time of their deposition, at least in the form of iron carbonate, although subsequent chemical action has undoubtedly changed these carbonates to hematite, and has probably continued the replacement of the lime of the fragments of shells and bryozoans forming the centers of the oolitic grains by these compounds of iron.

Plum Creek Clay.

The relations of the Plum creek clay to the underlying and overlying rocks are well shown along the lower part of Plum creek, about three miles southwest of Clay City, in Powell county. Here, along the western bank of Plum creek, directly east of the home of George McIntosh, an excellent exposure of almost the entire thickness is presented. (Fig. 3.) Farther down the creek, the base of the clay is exposed. The total thickness of the Plum creek clay is about five and a half feet, but opposite the home of George McIntosh the thickness of the exposure is five feet three inches, the base not being seen. The clay rests upon a strongly wave-marked layer of limestone. Beneath the wave-marked layer occurs the layer with large crinoid beads and with *Whitfieldella subquadrata*. The contact with the base of the Oldham limestone, at the top of the clay section, is clearly exposed.

One of the best exposures of the Plum creek clay occurs about a mile and a half northwest of Indian Fields, west of Howard creek, along the Lexington & Eastern Railroad. Here the thickness of the Plum creek clay is five feet. (Fig. 2.) The underlying layer of limestone is strongly wave-marked, as along Plum creek. Beneath the wave-marked layer is limestone containing the large crinoid beads and a few specimens of *Whitfieldella subquadrata*. Above the Plum creek clay, there is an excellent exposure of the lower part of the Oldham limestones, eight feet thick. The Plum creek clay section includes a little interbedded limestone at the top. Thin streaks of limestone occur also in the lower part of the section at irregular intervals.

Fig. 2. Brassfield Limestone, Plum Creek Clay, Oldham Limestone. A mile and a quarter west of Indian Fields, along the Lexington and Eastern Railroad, Clark County.

Between Brassfield and Panola, along the Louisville & Atlantic Railroad, the Plum creek section is underlaid by massive limestone, two and a half feet thick, containing *Whitfieldella subquadrata* in the lower part. Below the *Whitfieldella* layer, there is a layer of limestone with large crinoid beads at the top. The base of the Plum creek section consists of thin limestone and clay interbedded, having a total thickness of one foot ten inches. This is overlaid by the main clay section, three feet three inches thick, and the latter is followed by limestone interbedded with clay, three feet four inches thick. The upper part of this section forms a transition to the thicker bedded Oldham limestones above.

East of College Hill, nine miles north of Panola, the Plum creek section, four feet three inches thick, consists chiefly of clay, but the lower part, ten inches thick, contains thin layers of limestone.

Half a mile south of Whites Station and four miles north of Berea, the Plum creek section is about five feet thick, and consists of clay interbedded with several layers of thin limestone.

About three miles north of Crab Orchard, on the Fall Lick road, just before reaching Harmon Lick creek, the Plum creek section is about five feet thick. It consists chiefly of clay, but contains also interbedded layers of thin limestone.

About five miles west of Crab Orchard, on the county road near the home of James Thomas Bailey, the layer of limestone containing the large crinoid beads is overlaid by a layer of solid limestone, a foot and a half thick, corresponding to the *Whitfieldella subquadrata* layer. This is overlaid by clay, one foot thick; followed by limestone, four inches thick; and clay, one foot thick, all belonging to the Plum creek section. The upper part of the Plum creek layer at this locality probably was eroded before the deposition of the Devonian limestone.

No careful study has been made of the Plum creek clay southwest of the section between Brassfield and Panola. In the area between Clay City, Indian Fields, and the Red river, the Plum creek section consists chiefly of clay, often with but a very small amount of thin, interbedded limestone. Here the clay section, although only five feet thick, is sufficiently distinct from the fairly solid Oldham and Brassfield limestones, above and below, to attract attention. Farther southwest, especially be-

yond Brassfield, the quantity of interbedded limestone appears to increase, so that, although the clay preponderates, there is enough thin limestone to make the Plum creek horizon far less conspicuous. Still farther west, beyond Crab Orchard, the proportion of limestone in the Plum creek section is at least equally great, if not greater.

To an investigator entering the field from the southwest, the Plum creek horizon does not form a readily distinguishable feature until the southern part of Madison county is reached. Even in Madison county, southwest of Panola and Brassfield, the idea of separating the Plum creek clay from the Oldham limestone does not suggest itself. Farther north, between Indian Fields and Clay City, however, this clay forms a readily recognizable horizon.

There is no question of the increase of the amount of limestone in the Plum creek section on going from Indian Fields southwestward toward Stanford. Near Indian Fields, the thickness of the Plum creek bed is five feet. Southwestward, the thickness varies considerably, and, in general, appears to become somewhat thinner. Locally, however, sections five feet thick appear to occur even as far west as Crab Orchard, but this requires further observation.

Further investigations are necessary also in the territory between Hillsboro, in Fleming county, Kentucky, and West Union, in Ohio. The stratigraphy of this territory has by no means been worked out with the exactness which is desirable.

There is no prospect of the Plum creek clay having any commercial value. Even if it had any special value, it would not pay to work it, since the clay is overlaid by the Oldham limestone which must be removed in order to get at the clay. The Alger clay, overlying the Oldham limestone, agrees so closely, chemically, with the Plum creek clay where the latter is most free from limestone, that it is certain that the Alger clay will be exploited in preference to the Plum creek clay. The chief interest in the Plum creek clay is its stratigraphical position. In a study of the clay resources of the State it becomes necessary not only to determine where the large clay layers are, but also to determine the location and thickness of the subsidiary layers. Much money is wasted at times in operation where it is hoped that clays, limestones, or other layers

Fig. 4. Oldham Limestone, east of Brassfield, along the Louisville and Atlantic R. R. View of farther end of cut shown in Fig. 5.

Fig. 5. Oldham Limestone, east of Brassfield, along the Louisville and Atlantic R. R.

deep valley. In fact, between Brassfield, Indian Fields, Clay City, and Irvine, it occurs wherever the proper horizon is exposed.

Four miles north of Berea, in the railroad cut south of Whites, the limestone containing large crinoid beads and *Whitfieldella subquadrata* is overlaid by the equivalent of the Plum creek clay, five feet thick. It consists here of clay interbedded with clay rock. The Oldham limestone section is represented by limestone interbedded with clay, eight feet three inches thick. *Stricklandinia norwoodi* occurs at the top of this section. The overlying limestone one foot three inches thick may belong to the Devonian. The layer with fish remains occurs immediately above, and unquestionably is of Devonian age. Although this layer with fish remains usually forms the base of the Devonian section, it is underlaid by one or two feet of Devonian limestone at Elliston, near Kiddville, and at several other localities.

The identification of the Oldham limestone southwest of Berea is attended with difficulties owing to the absence of the *Stricklandinia* and to the gradual change of the lithological conditions. Eventually, as the result of careful stratigraphical work, the exact equivalency of all the more southwestern strata no doubt will be determined. At present, it is possible only to indicate what conclusions are favored by the evidence at hand.

A mile southeast of Hammack, the thickness of the Plum creek section is estimated at four feet four inches, and that of the Oldham limestone at approximately twelve feet. Half a mile north of Hammack, the thickness of the Plum creek section is estimated at five feet, and that of the Oldham limestone at ten feet three inches. Three miles north of Crab Orchard, on the road to Hammack and Richmond, the layer with large crinoid beads is overlaid by solid limestone, a foot and a half thick. Over this is found considerable clay, five feet thick, interbedded with limestone, forming the Plum creek section. This is followed by limestone interbedded with clay, eleven feet eight inches thick, belonging to the Oldham limestone horizon. About three miles west of Crab Orchard station, along the county road, near the home of Abel Bryant, the layer with large crinoid beads is overlaid by a section poorly exposed, five feet thick, assumed to belong to the Plum creek section. Above this occurs limestone interbedded with clay, twelve feet thick, regarded as belonging to the Oldham limestone horizon.

If these sections west and southwest of Berea have been interpreted correctly, there is no very evident thinning of the Oldham limestone between Indian Fields and Crab Orchard, although local variations in thickness are apparent.

The Oldham limestone may be readily identified by stratigraphic means as far as Owingsville. At the Rose Run iron ore quarries, the Oldham limestone forms the top of the exposures, and is separated by a very characteristic bed of Plum creek clay from the ferruginous, oolitic layer overlying the top of the Brassfield limestone. Farther north, however, considerable thin limestone occurs in some sections of the Plum creek clay, and the difficulty of discriminating between the Plum creek clay section and the Oldham limestone is considerably increased. In general, the Plum creek clay is to be regarded as a comparatively local formation, best developed between Owingsville, Clay City, Irvine, Brassfield, and Indian Fields. Where this clay can not be readily identified the Oldham limestone can not be readily discriminated. In such territories, the general designation, Indian Fields formation, may be used to include both the Plum creek clay and the Oldham limestone.

It has already been stated that farther northward, in Ohio, the Oldham limestone appears to find its equivalent in the Dayton limestone. In east central Kentucky the fossils of the Oldham horizon are neither numerous nor well preserved, but enough have been seen to indicate a fauna distinctly different from that in the Waco limestone layers.

Lulbegrud Clay.

The Lulbegrud clay directly overlies the Oldham limestone. In the territory between Irvine, Clay City, Indian Fields, and Brassfield, the thickness of the Lulbegrud clay is about thirteen feet. It is well exposed at various points along the tributaries of Lulbegrud creek, in Clark and Powell counties. About a mile southwest of Indian Fields, south of the railroad, there is a road leading from the creek road to Clay City northward across the railroad toward Clay City. Here the top of the Oldham limestone is well exposed a short distance above the level of Lulbegrud creek. Above this Oldham limestone, along the road, the full thickness of the Lulbegrud clay is exposed. The

Fig. 6. Top of Lulbegrud clay. Road side gully, one mile south-east of Indian Fields, north of Lulbegrud creek, along the road passing northward across the railroad track toward Kiddville.

clay is covered by a very persistent layer of limestone, above which the very thin layers of limestone characteristic of the Waco horizon are seen. (Fig. 6.) The home of Brownlow Bruner is scarcely a quarter of a mile directly west of this line of exposures, and this locality therefore has been called the Brownlow Bruner locality.

The Lulbegrud clay is exposed also at Abbott's mill, five miles south of Indian Fields, near the home of J. T. Elkins, along the road to Vienna; at several localities near Vienna, on the Red river; a mile east of College Hill, along the road leading to the dam; immediately south of Waco, along the road leading up hill; east of Panola, between the road and the railroad; within three hundred yards of the station; and southeast of Brassfield, along the railroad.

One of the best exposures of the Lulbegrud clay is seen north of Irvine, along the road passing Estill Springs, before reaching White Oak creek, and, again, up the hill, northeast of the point where the road leaves the creek. Here the thickness of the Lulbegrud clay varies between thirteen feet and fourteen feet and a half. On weathering, it softens into a bluish-white clay. The percolating waters often are impregnated with Epsom salts, and springs issuing from these clays belong to the class known as Licks. Gypsum is deposited from these waters. Good crystals are abundant at some localities.

Between Brassfield and Berea the sections become thinner. Three miles slightly north of east of Bobtown a thickness of ten feet is exposed, but the base is not seen. A mile and a half south of east from Bobtown, the thickness of the Lulbegrud clay is twelve feet. Two and a half miles southeast of Bobtown, the interval between the top of the Brassfield bed and the solid limestone regarded as marking the base of the Waco horizon is sufficient to suggest at least ten feet of Lulbegrud clay as forming a part of this interval. About two miles northeast of Berea, the thickness of the Lulbegrud clay appears to be nearly thirteen feet; three miles north of Berea, along the railroad, the thickness is estimated at eleven feet. Three miles southwest of Berea, the total Silurian section beneath the solid limestone layer, regarded as marking the base of the Waco horizon, is sufficient to warrant an estimate of ten to thirteen feet for the Lulbegrud clay division of this section.

The solid layer of limestone, varying between nine and twenty-four inches in thickness, which overlies the Lulbegrud clay section, has not been traced with certainty beyond Berea. Until a more detailed examination of the territory between Brassfield and Crab Orchard has been made, it is useless to hazard any opinion as to whether the solid layer of limestone found in more southwestern sections is of the same age or not. This layer of limestone also varies between nine and twenty-four inches in thickness, occurs at some distance above the base of a more continuous clay section, and has a rather wide geographical distribution, near Crab Orchard, and as far eastward as Berea. If this limestone layer at Berea and westward could be proved to be of the same age as the limestone overlying the Lulbegrud clay north of Irvine, Panola, and Brassfield, this fact would be of interest, since in that event a distinct thinning of the Lulbegrud clay toward the crest of the Cincinnati geanticline could be shown. Near Crab Orchard, the thickness of the clay between the solid limestone layer can not exceed six feet, and this is the thickness also at Hammack.

Waco Limestone Horizon.

Immediately above the Lulbegrud clay, about thirteen feet above the base of the great clay section here known as the Alger formation, there occurs a layer of solid limestone, varying from less than one foot to fully two feet in thickness. This is followed by numerous layers of fossiliferous thin limestones interbedded with a considerable quantity of clay. Although the clay predominates, this part of the section has been called the Waco limestone horizon, since the presence of the limestone is its characteristic feature. The layer of limestone at the base of the Waco section has been traced over the entire area included between Brassfield, Irvine, Clay City, and Indian Fields, a territory twenty-five miles long and twelve miles broad. No limestone, with which this limestone at the base of the Waco section could be confused, is known at any other elevation in the Alger formation. Hence it has been found a valuable horizon marker in the area designated. Possibly it may prove to extend both farther north and farther south. In that case it may serve to indicate the base of the Waco horizon even where

Fig. 7. Waco bed; a part of the Alger formation. A quarter of a mile north of the Estill Springs Hotel; north of Irvine, Estill county, on the eastern side of the pike.

the fossiliferous beds characteristic of this horizon are unknown. An attempt has been made to identify with this solid limestone at the base of the Waco section, the various exposures of limestone having about the same thickness occurring in the Alger clay section between Brassfield and Berea, but the interval between the top of the Oldham limestone and the heavy layer of limestone thus identified differs so much at various localities, that only detailed stratigraphical work can establish their identity, in the absence of the fossiliferous part of the Waco section. West of Berea, at Hammack, and at Crab Orchard, the solid layer of limestone occurs only six or seven feet above the base of the more continuous clay section. If this limestone represents the limestone at the base of the Lulbegrud clay, there is no question of the thinning of the Estill clay toward the west of Panola and Brassfield. Further investigations, however, are necessary to determine this question.

The fossiliferous layers, here called the Waco bed, are found at every locality between Indian Fields, Clay City, Irvine, and Brassfield so far investigated, where this horizon is exposed. The name has been taken from Waco, a small village east of Moberly station, in Madison county. The exposure occurs about half a mile east of Waco, along the road turning off from the Portland or Bybeetown pike toward Cobb ferry. Here the layer of solid limestone is overlaid by the fossiliferous Waco section, about ten feet thick, consisting of clay with interbedded layers of very thin limestone. The Waco horizon is overlaid by clay, three or four feet thick, followed by Devonian limestone.

The most instructive sections occur north of Irvine (Fig. 7), along the road passing Estill Springs, just before reaching White Oak creek. The layer of solid limestone here has a thickness of two feet. Immediately above, there is a section, ten feet thick, consisting chiefly of clay, but containing so many layers of thin limestone that the rubble from these layers forms the most conspicuous part of the exposure. Fossils occur both in the layers of limestone and in the clay. Corals predominate. Bryozoans are numerous. Other fossils are comparatively scarce.

Another exposure occurs farther north, along the road turning off from the pike as it reaches White Oak creek. This road passes the home of James F. Harris. Here the section con-

tains few fossils. Following the road along White Oak creek, to a point less than a quarter of a mile northeast of the home of Mr. Harris, another road leads toward the east, up the hill. Here the top of the Oldham limestone, containing *Stricklandinia norwoodi*, is overlaid by Lulbegrud clay, fourteen feet six inches thick; followed by the solid limestone layer, two feet thick; the fossiliferous Waco section, ten feet thick; clay with fragments of thin, argillaceous, and comparatively hard, shale, seven feet six inches thick; and soft clay, fifty-six feet thick. The same fossils occur as at the locality nearer Irvine. The lower part of the fossiliferous Waco section contains comparatively little limestone. In the upper part of the Waco section, limestone is more abundant.

The exact reverse of this is found at the Brownlow Bruner locality, a mile southeast of Indian Fields. Here a connecting road leaves the creek road to Clay City, and passes north toward Kiddville. Within a short distance of the creek, the top of the Oldham limestone is exposed. This is overlaid by Lulbegrud clay, thirteen feet thick; the solid limestone layer, nine inches thick; the fossiliferous Waco limestone layers interbedded in a clay section, eight feet three inches thick; and soft clay, twelve feet thick. Most of the fossiliferous layers of thin limestone are found in the lower half of the Waco section, and in the upper part of the Waco section the limestone layers are very thin and far apart.

Between Virden and Clay City, the upper part of the Waco bed, containing characteristic fossils, occurs at numerous localities along the railroad, a short distance below the Devonian limestone, or almost in contact with the latter.

About two miles southwest of Clay City, on the northern side of Tipton ferry, the solid limestone layer, one foot four inches thick, is overlaid by the fossiliferous Waco bed. This part of the section is exposed also along the road crossing Plum creek, about a mile southwest of Tipton ferry.

At the great clay pit, half a mile northwest of Indian Fields, the top of the Waco horizon is exposed. A quarter of a mile south of Indian Fields, along the pike, the top of the Oldham limestone, containing *Stricklandinia norwoodi*, occurs in the bed of the creek beneath the first culvert. This is overlaid by Lulbegrud clay, thirteen feet thick; the solid limestone layer,

nine inches thick; and clay, twenty feet thick, of which the lower half is fossiliferous and belongs to the Waco horizon. The exposure of the Waco bed is poor, but careful search showed the presence of a considerable number of characteristic fossils along the various branches of the creek in the fields toward the west.

The fossiliferous Waco bed is exposed also half a mile east of College Hill, along the road; and four miles north of College Hill, along the abandoned part of the road to Bloomingdale. At these localities the layer of solid limestone is only six to eight inches thick. On the Bloomingdale road this limestone is overlaid by clay, five feet six inches thick, in which no fossils were noticed. Overlying this, however, was a section, also five feet six inches thick, in which numerous characteristic fossils occurred. Here the clay contained thin layers of limestone chiefly in the upper part of the Waco section.

From these statements it may be seen that the fossiliferous Waco section has a comparatively wide distribution. No attempt has been made as yet to trace it farther northward or southward than the localities here listed, but the presence of some species of *Arachnophyllum* in the Alger formation of Bath county, identified by Linney as *Strombodes pentagonus*, suggests the presence of the Waco bed as far north at least as Bath county.

It is hoped that further investigations may result in tracing the Waco horizon farther south and southwest than Brassfield. A few traces of fossils were found several miles west of Crab Orchard, at the proper horizon. It is very evident, however, even from the few observations made so far, that the Waco horizon is not very fossiliferous north of Indian Fields, or south of Brassfield, so that, even if the Waco horizon may be traced further, its typical development will remain within the borders indicated.

FAUNA OF THE WACO LIMESTONE HORIZON.

The following fossils have been found in the Waco limestones of east-central Kentucky:

Isochilina panolensis, not rare,
Calymmene niagarensis,
Encrinurus ornatus, common,

Illaenus cf. imperator,
Diaphorostoma niagarense, small, common,
Cyclonema cf. cancellatum, not rare,
Atrypa reticularis, small, abundant,
Parastrophia sp.,
Brachyprion cf. profunda,
Strophonella cf. tenuistriata,
Dalmanella elegantula, common,
Platystrophia reversata, common,
Hebertella sp.,
Orthis flabellites, Osgood variety, common,
Pholidops ovalis, common,
Stomatopora dissimilis,
Meekopora bassleri, very common,
Crepipora ? squamata, common,
Favosites gothlandica, common,
Favosites hisingeri-aplata, common,
Favosites declinata, common,
Syringolites huronensis, not rare,
Halysites catenulatus,
Heliolites spongiosa,
Heliolites subtubulata, varieties *distans* and *nucella,*
Lyellia eminula,
Zaphrentis intertexta, and varieties *irvinensis* and *juvenis,*
Zaphrentis chararata, not rare,
Lindstroemia lingulifera, not rare,
Polyorophe radicula, not rare,
Cyathophyllum densiseptatum, common,
Cyathophyllum sedentarium, rare,
Chonophyllum solitarium,
Arachnophyllum granulosum,
Arachnophyllum, mamillare-distans,
Cystiphyllum spinulosum, common,
Calostylis spongiosa, very common.

The Waco fauna characterizes an horizon between thirteen and twenty-five feet above the base of the Alger clay, and the Alger clay forms the Niagara shale horizon of the Ohio Geological Survey. It has been customary to correlate the Niagara shale of Ohio with the Rochester shale of New York. In that

case it should carry an approximately similar fauna. A comparison of the Waco fauna of Kentucky with the Rochester fauna of New York does not show as close an agreement as is desirable. The following species of the Rochester shale, for instance, are absent from the Waco horizon, as far as known at present:

Dalmanites limulurus,
Homalonotus delphinocephalus,
Lichas boltoni,
**Whitfieldella nitida,*
**Whitfieldella nitida-oblata,*
**Spirifer (Delthyris) sulcatus,*
**Spirifer crispus,*
***Spirifer niagarensis,*
***Spirifer radiatus,*
**Rhynchotrema cuneata-americana,*
***Orthothetes subplanus,*
Ichthyocrinus laevis,
**Eucalyptocrinus decorus,*
Stephanocrinus angulatus,
Caryocrinus ornatus.

The species preceded by one star (*) are found, in New York, already in the limestone lenses at the top of the Clinton; those preceded by two stars are found even in the upper part of the true Clinton, beneath the lenses. The absence of any species of *Spirifer* in the Waco limestone is especially noteworthy.

In the west, in Indiana, this Rochester shale fauna makes its first appearance in the upper part of the Osgood formation, in the so-called Osgood limestone, which overlies the thick clay section which forms by far the greater part of the Osgood formation. This so-called Osgood limestone could be placed stratigraphically just as conveniently at the bottom of the Laurel limestone as at the top of the Osgood formation.

As far as may be determined from the evidence at hand, the Alger clay corresponds to the thick clay forming by far the greater part of the Osgood formation as originally described in Indiana. The fauna of the Waco horizon in the Alger clay is found stratigraphically beneath the fauna in the so-called Osgood limestone of Indiana. The fossils listed from the Os-

good formation of Indiana were obtained from the so-called Osgood limestone, and not from the thick clay section, corresponding to the Alger clay. The first appearance of the Rochester shale fauna in the Cincinnati geanticline region is in the Osgood limestone, above the Osgood clay, or Alger clay, or Niagara shale horizon of these States. The Waco limestone fauna is a different fauna from that of the Rochester shale, and precedes the arrival of the latter in the west.

The thick Osgood clay of Indiana, the so-called Niagara shale of Ohio, and the Alger clay of east-central Kentucky may be the stratigraphical equivalents of the Rochester shale of New York, but they are not the paleontological equivalents. If they are the stratigraphical equivalents, then a part of the Rochester shale fauna must have reached the western part of New York already during the time of formation of the limestone lenses at the top of the Clinton, while in Ohio, Indiana, and Kentucky it did not reach any typical development before the close of the deposition of the great clays formerly identified as Niagara shale. The fauna of the Waco limestones is quite distinct from that of any Silurian formation in New York. It shows distinct affinities with the Silurian of Sweden, and appears to have entered the field across northern Lake Huron.

One of the most interesting results of these preliminary investigations of the fauna of the Waco limestones is the accumulating evidence of a fauna closely allied to that found in the Silurian of Gotland and in the Wenlock division of the Silurian in England. This fauna appears to be absent in New York and along the Appalachian areas of this country, and therefore may have been introduced into this country from the north, across the northern end of Lake Huron, rather than from the northeast. This is suggested by the presence of *Syringolites huronensis* in the Silurian of Manitoulin Island in the northern part of the lake, and by the presence of species in the Niagaran strata of Indiana, Illinois, and Wisconsin, suggesting affinities with those of northwestern Europe.

Among the species in the Waco limestone fauna may be mentioned *Syringolites huronensis*, which finds a near relative, structurally, in *Roemeria kunthiana*, of Gotland; *Lindstroemia lingulifera*, belonging to a genus represented both in Gotland and England; *Polyorophe radicula*, which may not be closely related to *Polyorophe glabra* of Gotland, but which shows sev-

blocks. They are of a dull yellow, but are much lighter in color than the rocks from the middle beds of the Hudson river (the Garrard bed) in other parts of the county. They harden, when placed above drainage, and become very durable.

"The soils derived from these rocks are sandy and easily eroded, consequently one sees many sterile spots in the parts of the county where they exist. They are better exposed in what are called the Bald Hills, than at any other locality. They range across the county from Madison to Lincoln, never forming very wide exposures, and are heavier on the Lincoln side. A single layer of this stone contains a small amount of petroleum, and sometimes through some of the heavier beds are seen crystals of celestine, and, in a few instances, small lumps of zinc blende. Casts of a small form of *Atrypa reticularis,* and some other, but indeterminable, forms are found in the sandstone. At the top of this sandstone are often a few inches of limestone, vesicular in structure. This structure is due to the former inclusion of fossils, which have been removed. While interiorly blue, this stratum turns red on exposure, owing to the oxidation of the iron that it contains.

"Lying on this limestone are from sixteen to twenty-five feet of mud shales or marls, with a few thin plates of limestone intercalated. The shales are blue, black, olive, and brownish-red; are soft and fragile, and decompose directly into stiff, tenacious clay. Crystals of selenite and iron pyrites are common, and the whole series is impregnated with magnesia. These shales are usually seen in the hillsides as white clays and sterile spots, but in one place they cover several miles of surface, except where cut through by hollows. These are the shales from which the celebrated Crab Orchard salts are manufactured, and which are more particularly noticed in my report on Lincoln county. The shales may belong to the Clinton group, but until they are connected with rocks which are undoubtedly Clinton, we may retain the name of 'Crab Orchard Shales.'" (Plate A.)

It will be noticed that the description of the so-called Medina rocks of Garrard county agrees closely with that of the rocks identified as Medina in Lincoln county. The single layer of stone containing a small amount of petroleum is the *Whitfieldella* layer, which often contains a little petroleum in the cavities left by the dissolution of the thick parts of the shell of this

in Ohio, where Silurian limestones conformably overlie the equivalents of the Alger clay, more exact knowledge of its original thickness is obtainable.

At West Union, the thickness of the Alger clay apparently is 148 feet, but part of this apparent thickness may be due to dip. At Peebles, northeast of West Union, the Niagara shale section of the Ohio survey is eighty-five feet thick. At Hillsboro, it is seventy-five feet thick. Farther north it rapidly diminishes in thickness and changes gradually into strongly calcareous clay interbedded with a considerable quantity of thin limestone. At Dayton, in Ohio, the equivalents of the Niagara shale, of southern Ohio, are about thirty feet thick.

From this it is evident that the strata known as Niagara shale, in Ohio, become rapidly thicker southward, at least as far as Lewis county. Whether, before the erosion preceding the deposition of the Devonian limestone, this increase in thickness of the equivalent Alger clay continued as far as east-central Kentucky, can not be determined at present.

Where the Waco limestone can not be identified, it is impossible to determine how much of the Alger clay is to be assigned to the Estill clay section. In these cases, provided the thick layer of limestone, belonging at the base of the Waco section, can be recognized, the name *Flades clay*, from Flades creek, east of Crab Orchard, may be used for that part of the Alger formation which includes both the Waco and Estill horizons.

Only two species of fossils have been identified so far from the Estill clay, both from the thin argillaceous shales interbedded with the clays at the top of the exposures west of Valley, in Lewis county. These are *Beyrichia lata-triplicata* and *Chonetes vetusta.*

Indian Fields Formation.

It has been found convenient to group some of the minor subdivisions of the Silurian, in eastern Kentucky, into larger divisions, here called formations. The lower one of these is the Indian Fields formation. This includes not only the Plum creek clay and the Oldham limestone, but also those layers of limestone beneath the Plum creek clay which are regarded as

belonging above the line of unconformity marked, in east-central Kentucky, by the *Whitfieldella subquadrata* and oolitic iron ore bed. The total thickness of these layers of limestone usually does not exceed one or two feet. This method of classification, evidently, is an attempt to give a paleontological basis to the divisions proposed, and, as long as such a classification is not used for purposes of mapping, it may have a certain degree of usefulness.

Farther north, in Adams county, Ohio, where the *Whitfieldella quadrangularis* layer is distinctly below the oolitic iron ore bed, it appears to be the iron ore bed, rather than the *Whitfieldella* layer, which marks the position of the unconformity.

The typical exposure of Indian Fields formation occurs about a mile and a half northwest of Indian Fields, along the railroad, and extends from the second good cut west of Howard creek, eastward as far as the great fill crossing the valley occupied by that creek. Equally instructive exposures occur along the railroad between Panola and Brassfield.

Alger Formation.

The Lulbegrud clay, Waco limestone horizon, and Estill clay have been united so as to form the Alger formation. This is essentially a clay formation, the total quantity of limestone in the Waco limestone section forming but an insignificant part of the Alger formation, taken as a whole. By far the best sections known occur north of Irvine, along the road passing Estill Springs. The most instructive section is that along a road leading from White Oak creek eastward up a steep hill, about a quarter of a mile east of the home of James F. Harris, since in this section all the members of the Alger formation may be distinguished readily. The section along the road passing the home of Mr. Harris, however, is a continuous section, and, although the Waco horizon here carries few fossils, this very fact is of interest, illustrating the rapid local variation of this horizon. Excellent exposures occur also east of Panola, along the railroad.

The formation takes its name from Alger, a station along the railroad between Panola and Irvine. Here a branch of Drowning creek exposes the formation, and since the name Irvine is preoccupied for another formation, the name Alger will serve

as at least a fairly good index of the region in which typical exposures of this formation may be found.

The various members of the Alger formation have already been described with sufficient detail to make any further description of the Alger formation, as a whole, unnecessary.

Crab Orchard Division.

The Indian Fields formation and the Alger formation have been united to form the Crab Orchard division of Niagaran rocks. This grouping is based upon a combination of stratigraphical and paleontological data, and is merely an effort to construct for the Silurian strata of Kentucky a system of groupings which will serve to indicate the stratigraphical equivalency of the Silurian strata of this State with corresponding strata in Ohio. In other words, the Brassfield limestone is believed to correspond to those strata which in Ohio have been identified as Clinton. The Crab Orchard division of Kentucky is correllated with the strata identified as the Niagara shale in Ohio. In Ohio, the Dayton limestone has been included in the Niagara shale section, forming the basal part of this section. In Kentucky, the Oldham limestone, believed to be the stratigraphical equivalent of the Dayton limestone, also is included in the lower part of the same division as the great mass of clays. But in Kentucky the great mass of clays is called the Alger formation, and the limestone regarded as equivalent to the Dayton limestone has been called the Oldham limestone.

From a lithological standpoint, this grouping of strata is perhaps not as natural as one in which the entire Silurian section of east-central Kentucky would be divided into two great divisions, consisting of a great lower division including chiefly limestone, but also one considerable clay deposit, and of a great upper division, consisting almost entirely of clay. In this case, the lower division would include the Brassfield, Plum creek, and Oldham beds, while the upper division would include all of the Alger formation. The arrangement adopted in the present bulletin is that best adapted to show the parallelism between the corresponding strata of Ohio and Kentucky.

The name Crab Orchard was introduced by Linney, in his report on Lincoln county. He did not define this term with the

exactness which is necessary for determining its exact equivalency with the various subdivisions here established. There is no doubt of the application of the name Crab Orchard to all of the Alger formation, but apparently Linney included also the Plum creek clay and its equivalents southwest of Brassfield. Under these conditions it has been considered desirable to give this name the widest significance which it possibly could have had, and therefore it has been employed for all Silurian strata of east-central Kentucky which lie above the Brassfield bed. This would include both the Indian Fields and Alger formations.

On account of their historical interest, the observations by Linney are republished on the following pages, with such comments as will serve to make clear the meaning in those cases where at present the language may appear obscure, and such further notes as will show the relationship of the divisions then in use to those now established.

Linney's Reports on the Silurian Rocks East of the Cincinnati Geanticline.

A. Lincoln County.

In the Report on the Geology of Lincoln County, by W. M. Linney, published in 1882, the following account is given of the Silurian rocks of the county:

"Medina Sandstone.—In the northeastern portion of Lincoln county there is to be seen, in a number of places, a series of buff sandstones, which sometimes show as hard concretionary shales, which are disposed to break into squares hardly more than an inch in diameter.

"These beds at their thickest points are about thirty-five feet in thickness; and erosion over them is comparatively rapid, and they leave a soil which is sandy and easy to wash. These tracts have a local name of 'Bald Hill Soils,' from a locality in Garrard county where the rocks are exposed, and so called because they have become, in places, sterile from the amount of sand which covers them.

"Internally they show yellow and green spots. Some of

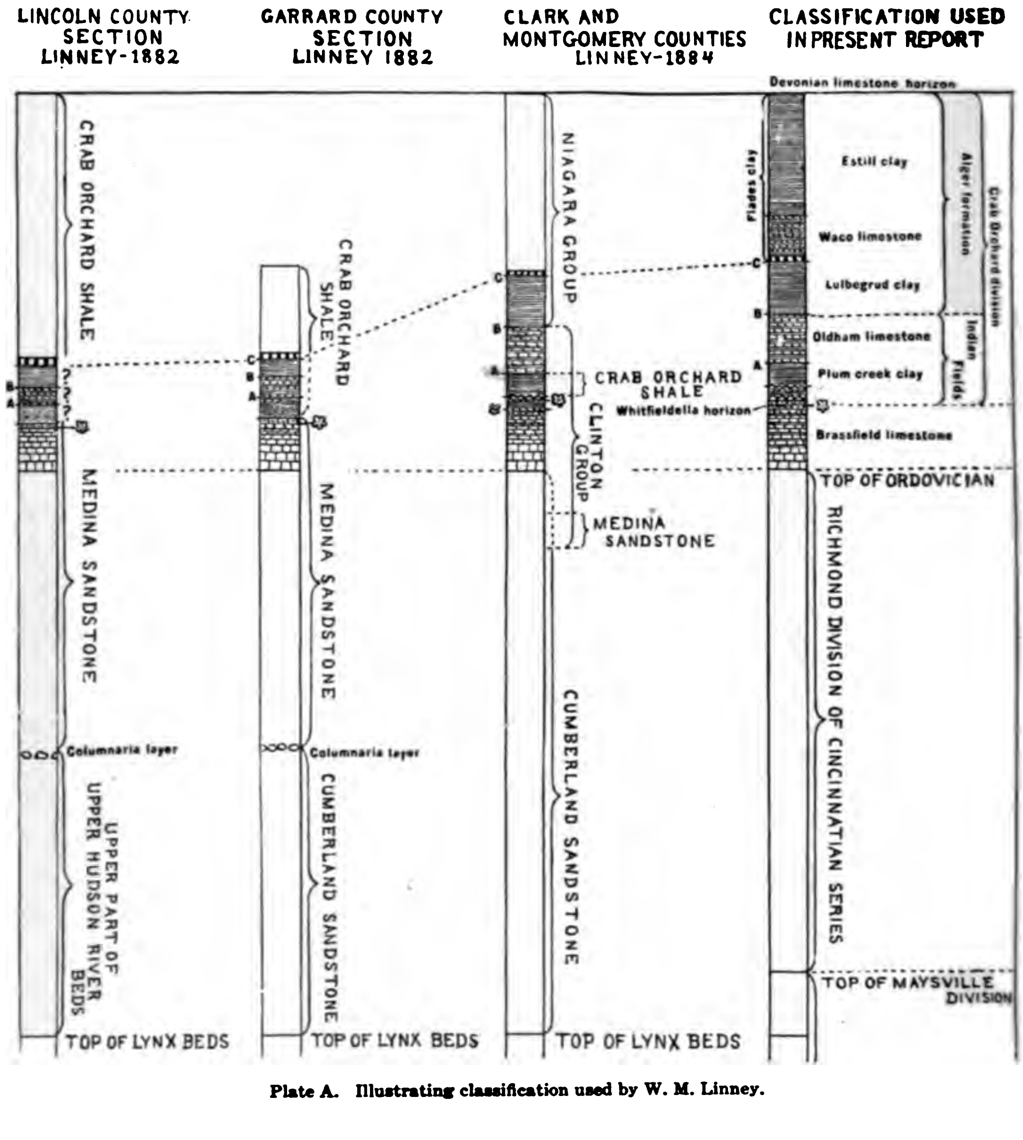


Plate A. Illustrating classification used by W. M. Linney.

the layers have a small portion of lime in them. This series is well exposed on a road leading from Richmond Junction (now called Rowland) to Dudderar's Mill, on Dix river (three miles northeast of Rowland, on the road to Gilbert Creek Station). Here, at many places in the hill-sides, can the *Columnaria* bed be seen covered up in the sand which was brought by the currents and swept over them.

"A little north and east of Hall's Gap Station, and on the road thence toward Crab Orchard, they may be seen as they are presented in Garrard and Madison counties. While at nearly every point exposed the layers seem worthless for building purposes, yet locally there are some fine durable stones among them. At Mr. J. T. Lynn's, about a mile (east) from Hall's Gap Station, stones were quarried for foundations, steps, etc.; a very desirable stone was obtained, which has every appearance of being durable. They are easily taken from the quarry, come out in good shape, and can be dressed with an axe, so soft is their character. They harden on exposure, and become of a deep buff color. At James' Mill, on Dix river (two miles north of Crab Orchard), the stack was made of stones taken from these beds, and nothing could have suited the purpose better.

"In every direction from Crab Orchard these rocks may be seen when looked for, presenting often small sterile spots; in some cases they have been built into stone fences. Some of the soils over these beds are fairly good where they have been taken care of; but too often they present the features which are mentioned in the report on Washington county.

"In some of the heavier layers, at particular points, are included a few geodes filled with calcite crystals of a pinkish color. In some instances I found small masses of celestite or *strontium sulphate* in a heavy hard layer near the top, and occasionally small nodules of zinc blende were seen.

"Many of the layers are remarkably full of sea-weeds; their branching and matted stems covering layers everywhere as far as they can be traced. One bed, a few inches thick, seems to have held branching forms of *Chaetetes* corals (now known as branching bryozoans); the cavities filled with petroleum. Fossils are very few, and exist only as very poor sandy casts. They probably include small forms of *Atrypa reticularis* (probably

the interior casts of *Whitfieldella cylindrica-subquadrata* showing little else than the muscular scars) and *Zaphrentis bilateralis* (probably the common cup-coral, here called *Cyathophyllum caliculum,* which is found in the upper part of the Brassfield or Clinton bed, just beneath the *Whitfieldella* layer); but such was their condition that they could not be determined satisfactorily.

"In the western portion of the county these rocks are seen between Moreland and Carpenter's station; but here they are thinner than in the eastern part, and present no new phases. The whole series has the appearance of being a reef-like accumulation, deposited largely or entirely by currents, and sometimes probably in the face of waves, as at several points one or two layers have a wave-like structure. The life which existed in the waters before seems to have all been destroyed here at this time, and during the invasions of the Medina sand (the rocks so identified in Lincoln county belong in part to the top of the Ordovician and in part to the base of the Silurian) seem not to have been fitted for anything but plant-life, except in rare instances, and for short duration.

"Crab Orchard Shale.—Overlying the Medina sandstone (see comment above) in the eastern part of the county is a group of clay shales, which reach in several instances a thickness of forty feet, but thin down in others to a mere trace. These shales, as seen in exposed places, are gray or white, sometimes green; but when freshly excavated are black, green, olive, blue, and red. They are soft and crumbling, and are soon reduced to clay, and when tramped in wet roads become stiff and tenacious.

"Within this deposit are a few hard smooth plates of thin limestones, with sometimes obscure markings of plants; these plates are hard, and are often seen where all the shales have decomposed. These plates, and sometimes the shales, have a curved structure, and at times some of the laminae overlap the thinned-out edges of others.

"Included in this bed are crystals of selenite (gypsum), and crystals and nodules of iron pyrites; sometimes a plate of iron shale is also seen. The whole bed seems to be impregnated with carbonate of magnesia. To the presence of those three minerals, in the form they assume, is due the peculiar character of the

magnesium compound, which, under the name of Crab Orchard salts, is manufactured from these shales. These shales are placed provisionally in the Clinton (they now are known to overlie the Clinton) until more is learned in regard to their relation. As these shales contain gypsum, soda, and potash, it would be advisable for farmers and others to make some experimental tests with them as fertilizers."

From the preceding paragraphs, quoted from the report on Lincoln county, it is evident that Mr. Linney divided the Silurian, as identified by him, into two divisions. The lower of these he correlated with the Medina of New York. Not being certain of the advisability of correlating the clay shales, forming the upper part of the Silurian section in this part of Kentucky, with the Clinton of New York, he called them the Crab Orchard shales. (Plate A, page 64.)

The "Bald Hill Soils" are of Ordovician age. They form that part of the Richmond group which overlies the *Columnaria* layer. The *Columnaria* layer was regarded as marking the base of the Silurian, whereas as present it is known to be at least seventy-five feet below the top of the Richmond, and to be underlaid by about the same thickness of almost unfossiliferous strata, also of Richmond age. Linney's estimate of thirty-five feet for that part of the Richmond section which overlies the *Columnaria* layer is manifestly incorrect, but this is true of most of his so-called measurements, which in reality were estimates made without the use of instruments. The fine durable stones, found locally between Hall's Gap Station and Crab Orchard, are of Brassfield or Clinton age. At James' Mill, on Dix river, two miles north of Crab Orchard, on the road to Preachersville, both the Oldham limestone and the top of the Brassfield limestone are exposed, but only the latter is hard and offers layers of suitable thickness for building purposes. The Brassfield limestone is the only one around Crab Orchard which has been built into fences. The heavier layers of limestone are also of this age. The fossiliferous beds undoubtedly belong at the top of the Brassfield section, since the upper part of the Richmond in this section is practically unfossiliferous. The remains identified as *Atrypa reticularis* must have been that part of the internal casts of *Whitfieldella subquadrata* which includes the impressions of the muscular scars of the

pedicle valve (Plate 1, figs. 3-A, B. C), since this is the form commonly associated with the small cup coral identified by Linney as *Zaphrentis bilateralis*. These fossils of the *Whitfieldella* layer form altogether too conspicuous features of the Silurian section to have escaped attention, and are the fossils with which these names were identified by local geologists ten or fifteen years ago.

The pockets of petroleum occur almost exclusively in the Brassfield and Devonian limestones, in this area. The strata between Moreland and Carpenter's station are of Ordovician age.

The Crab Orchard shale of this report includes the Alger clay. The thickness of forty feet is exceeded at all localities in the immediate vicinity of Crab Orchard. North of Crab Orchard, this thickness equals at least seventy-five feet, and its exact thickness is unknown, on account of the unknown dip and the great distance between the top and bottom of the section.

The hard smooth plates of thin limestone with obscure markings of plants are the thin plates of argillaceous shale scattered throughout various parts of the Alger formation. This is also the formation including the Crab Orchard salts.

From these notes it would seem most reasonable to assume that Linney practically included only the Alger clay in his original discussion of the Crab Orchard shale. There is no doubt that he included the *Whitfieldella subquadrata* layer in his Medina. Nothing is said any where which would determine his disposition of the Oldham limestone, but it seems most reasonable to assume that in this report it was included in the Medina.

B. Garrard County.

Linney's description of the rocks in Garrard county identified by him as Upper Silurian (now known as Silurian) is as follows:

"The rocks of the Upper Silurian in Garrard amount only to a thickness of some sixty feet, and have at the base thirty-five feet of sandstones, which are the probable equivalents of the Medina sandstone of New York. The greater part of this is a soft, easily pulverized sandstone, sometimes concretionary, containing in places some layers which have been used for building purposes. They quarry very easily, and in good well-shaped

species of *Whitfieldella*, near the hinge. This must be the horizon from which the so-called *Atrypa reticularis* was identified. It is undoubtedly the horizon described in the following terms: "At the top of this (Medina) sandstone are often a few inches of limestone, vesicular in structure. This structure is due to the former inclusion of fossils, which have been removed. While interiorly blue, this stratum turns red on exposure, owing to the oxidation of the iron that it contains." There is only one layer which shows these cavities and which has this ferruginous character, and that is the *Whitfieldella subquadrata* layer.

In this description Linney definitely limits the top of his Medina at the *Whitfieldella* layer, and appears to assign all of the overlying strata to the Crab Orchard shales. As a matter of fact he probably gave no thought whatever to the few layers of limestone belonging to the Oldham horizon. In Lincoln and Garrard counties, the equivalents of the Oldham limestone are too inconspicuous to receive attention in a general survey. Following, however, a literal interpretation of this first definite assignment of limits between the Medina and Crab Orchard shales, this limit must be drawn at the top of the *Whitfieldella* layer and not at the base of the Alger formation.

The estimates of the various thicknesses of the rocks described is again at fault. In his description of the Upper Hudson River beds of Garrard county, Linney definitely states that: "The top of these (Upper Hudson River) beds and of the Lower Silurian (Ordovician) is marked in places by an irregular mass of limestone, which is filled with large corals of the genus *Columnaria*, and associated with those are many other forms, such as *Tetradium*, *Streptelasma*, etc.; but often the Cumberland Sandstone is at the top, making it difficult to determine the dividing line between it and the next." As a matter of fact, the *Columnaria* layer of Garrard county does not contain many other fossils, *Columnaria* being almost the only fossil found. This part of Linney's statement is due, no doubt, to the presence of numerous fossils immediately above the *Columnaria* layers in Marion, Washington, and Nelson counties, with which he was familiar. The *Columnaria* layer was regarded as marking the line of division between the Cumberland sandstone and the Medina sandstone. The Cumberland sandstone of this description includes that part of the unfossiliferous Ordovician section

which lies beneath the *Columnaria* layer. It consists chiefly of strata of Richmond age, since the top of the fossiliferous beds beneath belongs to about the middle of the Arnheim layer, to the horizon containing *Leptaena rhomboidalis* and *Rhynchotroma dentatum*. Since, owing to the absence of other fossils, the *Columnaria* layer was about the only means, in Garrard county, of distinguishing the Cumberland sandstone from the Medina sandstone of Linney, it is evident that, where the *Columnaria* layer was absent, in other words, where the Cumberland sandstone formed the top of Linney's Lower Silurian, without the intervention of the *Columnaria* layer, it was difficult to determine the dividing line between it and the next.

The thickness of the section between the *Columnaria* layer and the *Whitfieldella* layer, the strata identified by Linney as Medina, is about eighty-five feet, instead of thirty-five feet. The thickness of the Silurian section overlying the *Whitfieldella* layer in Garrard county varies between twenty and sixty-five feet. That part of the section overlying the solid layer of limestone, believed to mark the base of the Waco horizon, varies in thickness from 0 to almost forty feet. From this it seems not impossible that some of the measurements of the Crab Orchard section were made from the solid limestone at the base of the Waco horizon rather than from the *Whitfieldella* layer.

C. CLARK COUNTY.

The reports on Lincoln and Garrard counties were published simultaneously, in December, 1882. They are both, therefore, given equal value in determining what significance should be assigned to the name Crab Orchard Shales.

Two years later, in 1884, in his report on Clark county, Linney changed both the classification and the nomenclature of the rocks which he had formerly included in the Silurian. He divided the rocks identified by him as Silurian into two divisions. The lower of these he considered equivalent to the Clinton of New York. The upper division he correlated with the Niagara group of that State, probably having in mind the Niagara shales, now known as the Rochester shale. The Medina was identified doubtfully, and a much smaller section was included under this

name than heretofore, in his description of the geology of Lincoln and Garrard counties.

Linney's description of the Clark county rocks identified as Clinton is as follows:

"The rocks of the Clinton are for the most part magnesian limestones and shales. At the base are some heavy sandy layers which may represent the Medina sandstone. These are more or less earthy and friable, crumbling into small pieces from the exposed layers, and when thoroughly reduced and washed of the clay there is left often, in places, only pure sand. These rocks contain some casts of shells in very poor condition, though the *Orthis lynx* is often one of them. Perhaps a small form of *Atrypa reticularis* is among them. These are succeeded by thinner layers of coarse-grained limestones and shales, then several layers of heavy, rough-bedded blue limestones, after which there are shales and thin limestones (in the following table these are given in the order—thin limestones and shales) overlaid with heavy strata of limestones.

"These present about the following section, though they are not by any means uniform in every place:

Heavy limestones	8 ft.
Shales	7 ft.
Thin limestones	9 ft.
Heavy limestones	6 ft.
Limestones and shales	11 ft.
Sandstones and shales	9 ft.
Total	50 ft.

"The larger part of the limestones are rough and unevenly bedded, breaking unevenly, and contain some silica and clay. These make a tough material for pikes and have been used for that purpose. While they are a dirty blue, when freshly broken, they all become, on exposure, a dirty yellow, which is so peculiar to magnesian limestones. There is rather more than 20 per cent. of magnesia in all these limestones. The thin layers are more even in character, and some of them would make flagstones.

"The seven feet of shales seem to be the equivalent of the Crab Orchard shale of Lincoln and Garrard counties. They contain the association of thin plates, balls of iron pyrite and

crystals of sulphate of lime. At Kiddville, at the residence of Mr. J. E. Groves, a well dug in these layers gave a strong epsom water similar to the Crab Orchard variety. These shales are blue and red, but on exposure they become ash-colored or white.

"At Kiddville and several other places one of the layers of limestone was red in color, due to the infiltration of iron. On further examination it was seen that there are two layers, which must be the representatives of the beds of hematite ore in the Clinton group in East Tennessee. The same lenticular structure is prevalent. Sometimes this is a true ore, with all the characters of the Clinton. There is some little strontian contained in these rocks, a very usual thing in Kentucky. *Pentamerus ovalis* and *Zaphrentis bilateralis* are very common fossils. Small forms of *Atrypa reticularis* and other fossils are found, but they are not good specimens."

Regarding the rocks identified as belonging to the Niagara group Linney states:

"Over the Clinton is spread sixteen to twenty feet of blue and red shales, which have intercalated about three inches of thin limestone plates. These make four layers and are filled with small fossils, usually round-stemmed corals (now known as bryozoans). They also contain *Strombodes pentagonus* and *Favosites niagarensis*. They seem to determine the position of this shale, which is the only representative of the (Niagara) group. This shale, when on the surface, gives a very stiff, tenacious clay, and when roads run over it and are not macadamized they become almost impassable. It can be best seen at Eastin's mill (a mile and a half east of Indian Fields), where there is a perpendicular section entirely through it."

The interpretation of these statements by Linney offers certain difficulties. The following interpretation appears most reasonable (Plate A):

Linney's work in Clark and Montgomery counties bridged the connection between Garrard and Bath counties. In Bath county were important deposits of the oolitic iron ore evidently similar in character and stratigraphical position to the oolitic iron ores in Adams, Highland, and Clinton counties, in southern Ohio. It was quite generally agreed that these oolitic iron ores of Kentucky and southern Ohio corresponded stratigraphically to those in the Clinton of New York, and that the overlying

clay shales corresponded to the Rochester shales of New York, then known as Niagara shales. It then became necessary to revise the classification of the rocks of eastern Kentucky so as to meet these views. The results are expressed in these reports on Clark and Montgomery counties, published under the same cover, in 1884.

In the report on Clark county, the Cumberland sandstone is stated to include a series of strata, about 125 feet thick, overlying the *Platystrophia lynx* beds. They include that part of the Arnheim layer overlying the *Leptaena rhomboidalis* and *Rhynchotrema dentatum* horizon, and also all of the Richmond section, excepting possibly some of the strata very near the top. As a matter of fact, the interval between the *Rhynchotrema dentatum* layer and the top of the Richmond in this area is estimated at approximately 145 feet.

The section of rocks, published in connection with Linney's description of the Clinton group, probably was obtained along the Lexington & Eastern Railroad, which, at the time of Linney's investigations, was in the process of grading. Railroad cuts were exposing all the strata northwest of Indian Fields, and Mr. Linney was a frequent visitor at the home of John Goff, a mile south of Indian Fields. The rocks identified as possibly representing the Medina sandstone must be a part of the upper Richmond, since these are the only strata which are earthy, and friable, and which weather to a sandy mass. These rocks also are the only ones in which poor remains of a small species of *Platystrophia*, incorrectly identified as *Platystrophia lynx*, are at all frequent. The form identified by Linney as *Atrypa reticularis* may have been poor specimens of *Strophomena sulcata*, or poor specimens of *Hebertella*. The shales, seven feet thick, undoubtedly belong to the Plum creek horizon. The overlying mass of heavy limestones belong to the Oldham section. The limestones below the Plum creek section belong to the Brassfield bed. The thin limestones forming the upper part of this bed are the fossiliferous part of the section. The heavy limestones beneath form the base of the Brassfield bed. The underlying limestones and shales, said to be eleven feet thick, and overlying the sandstones and shales identified doubtfully as Medina, probably form the very top of the Richmond section, overlying the fossiliferous layers of this part of the Richmond.

The seven feet of shales of this section, called the Plum Creek clay in the present bulletin, were identified by Linney with his Crab Orchard shales on the basis of the thin limestone plates, the balls of iron pyrites, but more especially upon the epsom salts which they contain, a peculiar form of stratigraphic identification not unknown in more recent times. The ferruginous layers at Kiddville, identified with the beds of hematite ore in the Clinton group in East Tennessee, belong to the *Whitfieldella* horizon, and to a second layer about two feet higher up, just beneath the Plum creek clay. The *Pentamerus ovalis* of Linney probably consisted of good specimens of *Whitfieldella subquadrata,* broken out of the rock and almost entire. The *Atrypa reticularis* could hardly have been anything except the interior casts of the upper part of the shell of the same *Whitfieldella,* close to the hinge line, especially parts showing the impressions of the muscular areas in the pedicel valve. *Zaphrentis bilateralis* is the very common simple coral to which the name *Cyathophyllum calyculum* has been applied in the present bulletin.

The Niagara group of Linney's report on Clark county includes the Alger formation. In the neighborhood of Indian Fields only the Lulbegrud clay, the Waco horizon, and the base of the Estill clay are exposed. At most localities in the northern part of the county the thickness of the Estill clay does not exceed ten feet, and occasionally it is less than five feet. The thickness of the Lulbegrud clay is about thirteen feet. That of the Waco limestone is about nine feet. So that here, as elsewhere, the measurements of Linney are not strictly accurate.

The fossils in the thin limestones came from the Waco horizon. The small, round-stemmed corals are now known as bryozoans. *Strombodes pentagonus* is some species of *Arachnophyllum. Arachnophyllum mamillare-distans* is the most common species in the vicinity of Indian Fields. *Favosites niagarensis* occurs, although other species are more common. The section of clay at Eastin's mill belongs to the Lulbegrud horizon. The well dug on the J. E. Grove property, northeast of Kiddville, on the Levee road, penetrated the same clay, the Lulbegrud horizon.

D. Montgomery County.

In the report on the geology of Montgomery county, Linney uses about the same divisions of the strata, considered by him

as Silurian, as in the case of the report on Clark county. The Clinton group is described as being sixty feet thick, an increase of ten feet in thickness if compared with the Clinton group of Clark county. This is ascribed to an increase in thickness of the sandy (Ordovician) layers at the base, which, in the more western counties, Marion and Nelson, were identified as Medina sandstone. Above this sandy rock resembling the Medina, according to Linney, occur the rough-bedded, heavy limestones (the Brassfield bed), the shales identified by Linney as the Crab Orchard shales (the Plum creek clay), and somewhat heavier massive layers, of which one, in one or two places, shows well a wave-like structure with large ridges (the Oldham limestone). The Niagara shale (the Alger clay horizon) has about the same thickness as in Clark county, about eighteen feet. (Plate A.)

E. Bath County.

In the report on the geology of Bath county, published in 1886, Linney divides the rocks which he identifies as Silurian into three divisions: the Medina, Clinton, and Niagara. To the Medina he assigns only ten feet of rock, sandy, more or less interbedded with shale, at present known to belong to the top of the Richmond division of the Cincinnatian series of rocks. To the Clinton he assigned limestones and shales having a total thickness of thirty-four feet, and presenting the following average section, described in descending order:

Thin limestones and shales	2 ft.	
Limestone		10 in.
Shale	1 ft.	9 in.
Limestones		11 in.
Shales and thin limestones	4 ft.	
Iron ore	2 ft.	
Thin limestone	3 ft.	
Limestone layer	1 ft.	
Wave-marked layer	1 ft.	3 in.
Thin limestones	3 ft.	
Shales	6 ft.	
Heavy limestone with chert	9 ft.	
Total	34 ft.	9 in.

The upper four members of this section, having a total thickness of five and a half feet, belong to the Oldham horizon.

The shales and thin limestones, four feet thick, represent the Plum creek section. Where the exposures are perfectly fresh, so that none of the limestone layers have slumped down over the soft clays, the Plum creek section in the neighborhood of Owingsville is seen to vary between seven and eight feet in thickness. The layer of iron ore, two feet thick, includes at its base the *Whitfieldella subquadrata* section. Wave-marked layers of limestone come in at several levels in the upper part of the Brassfield bed, usually within four feet of the iron ore bed, but sometimes immediately below the latter, and occasionally one of the layers immediately over the iron ore bed is wave-marked. This merely corroborates the testimony furnished by the pebbles just below the iron ore bed in some parts of southern Ohio, that there was shallow water during the deposition of the last parts of the Brassfield bed and during the formation of the *Whitfieldella* and oolitic iron ore beds. The heavy limestone with chert at the base of Linney's section forms the base of the Brassfield bed.

The following fossils were identified as occurring in the rocks associated with the iron ore, probably occurring chiefly at and immediately below this horizon: *Zaphrentis bilateralis (Cyathophyllum calyculum)*, small short forms of *Atrypa reticularis* (casts of muscular areas of *Whitfieldella*), *Favosites niagarensis*, a short oval form of *Pentamerus (Whitfieldella subquadrata)*, a *Chaetetes* (some round-stemmed bryozoan), and large numbers of crinoid fragments.

The clay shales identified as Niagara in Bath county belong above the Oldham limestone horizon. They are said to vary in thickness from twenty feet in the western part of the county to 100 feet in the eastern part. Linney states that the peculiar features of these shales in Bath county are to be seen also around Crab Orchard, showing that he recognized that these clay shales, here identified as Niagara, found their equivalents in the clays above the Oldham horizon at Crab Orchard, in spite of the fact that in Clark county and in Montgomery he identified the Plum creek clay as Crab Orchard and used the term Niagara for the Alger clays occurring higher in the series. The presence of the Waco horizon is suggested by the identification of *Strombodes pentagonus* among the few fossils occurring in these so-called Niagara clays.

F. Fleming County.

In the geology of Fleming county, published in 1886, the strata identified as Medina (belonging to the top of the Ordovician) are said to be twenty feet thick. The heavy, cherty beds at the base of the strata identified as Clinton, are said to be eight to ten feet thick. The wave-marked layer, farther up in the series, is stated to be very persistent. The iron ore also is found at several localities, although usually absent. The strata identified as belonging to the Niagara group consist almost entirely of clay shales, belonging to the Alger horizon.

G. Mason County.

In the report on Mason county, written in 1885, sandy rocks and clay shales, twenty feet thick, and belonging near the top of the Ordovician, are identified as Medina. The rocks identified as Clinton are stated to have a thickness of thirty-five feet. These are said to consist of twelve feet of blue shales at the base (forming the top of the Ordovician), eleven feet of limestone, the larger part containing chert, and thirteen feet of shales alternating with layers of limestone. The strata identified as Niagara consists of fifteen or more feet of blue clay shales, weathering to a white clay soil; this part of the section probably belongs above the Oldham horizon, but represents only the base of the Alger formation, much greater thicknesses of the Alger clay being found farther east, in the exposures in Lewis county.

Marion County.

Linney correlated with the Crab Orchard shales also certain clay shales west of the Cincinnati geanticline, to the Indiana equivalent of which the name Osgood shales has been given. In the report on the geology of Nelson county, published in 1884, Linney refers to the Crab Orchard shale horizon the Osgood clay shales seen so well exposed near the Church of the Holy Cross in Marion county, not more than a mile and a half east of the Nelson county line. Knott, in his geology of Marion county, published in 1885, repeated this reference of the Osgood clays near Holy Cross Church to the Crab Orchard horizon. In the report on Oldham county, published in 1887, Linney does not refer to the Crab Orchard shales.

Beginning with his reports on Clark and Montgomery counties, written in 1884, Linney appears to have become so thoroughly satisfied as to the Niagara age of the great mass of clays forming the upper part of the Silurian section on the eastern side of the Cincinnati geanticline, in Kentucky, and as to the Clinton age of the underlying limestones and clays, that he had no further use for the term Crab Orchard shales, and therefore abandoned it. The most difficult thing to understand is why, in the reports on Clark and Montgomery counties, he should have identified the Plum creek clay as Crab Orchard shale, and have made no reference to the Crab Orchard shale in his description of the far greater mass of clay shales which he identified as Niagara.

It also is difficult to understand how he secured some of his measurements. In some cases it is absolutely impossible to verify these. He must merely have estimated these without any attempt at measurement. Nevertheless, aside from the restrictions here made, Linney did a great deal of faithful work on the geology of the limestone counties of the middle portions of Kentucky. He was obliged to cover large areas in a short period of time and without the advantages offered by later observations in other parts of the field. His reports, in spite of all their defects, have furnished an excellent basis for further work, were a great advance on anything done before in the State, and always will stand as a monument to his industry.

The Classification of Devonian Rocks.

DEVONIAN LIMESTONE.

Lithologically the Devonian deposits of Kentucky may be divided into two divisions, in descending order:

The Devonian Black Shale, and

The Devonian Limestone.

The Devonian limestone of Ohio is divided into the following formations, named in descending order:

Delaware limestone,

Columbus limestone,

Unnamed division, nearly unfossiliferous.

The Devonian limestone of western Kentucky and southern Indiana is divided into the following formations, also named in descending order:

Sellersburg limestone,
Jeffersonville limestone,
Geneva limestone, nearly unfossiliferous.

FAUNA OF DEVONIAN LIMESTONE.

A list of the fossils found in the Columbus limestone within twenty-four miles of Columbus, Ohio, was prepared by E. and H. Hyatt and published by Prof. R. P. Whitfield in the Geology of Ohio, Vol. VII, page 434, in 1893. The fossils of the Jeffersonville and Sellersburg formations were described by E. M. Kindle in the Twenty-fifth Annual Report of the Indiana Survey, page 579, in 1901. A study of the brachiopoda of these faunas has suggested the following methods of comparison:

Among the species listed by R. P. Whitfield as occurring in the Columbus limestone within twenty-four miles of Columbus, Ohio, the following are not cited from the Devonian of Louisville, Kentucky, or from Indiana. The range of these species outside of Ohio is indicated in each case.

Rhynchonella (?) *raricosta.*
Camarotoechia billingsi; New York, Ontario.
Camarotoechia dotis; New York.
Charionella scitula; New York, Ontario.
Spirifer macrothyris; New York, Ontario.
Spirifer marcyi; New York.
Stropheodonta inaequiradiata; New York, Canada, Nevada.
Stropheodonta patersoni; New York, Illinois.
Strophonella ampla; New York, Ontario.
Orthothetes flabellum.
Orthothetes pandora; New York, Ontario, Nevada.
Schizophoria propinqua; New York.

Among the species listed by R. P. Whitfield as occurring in the Columbus limestone within twenty-four miles of Columbus, Ohio, the following are cited also from the Jeffersonville limestone of Louisville, Kentucky, or from Indiana. The distribution of these species outside of Ohio, Kentucky, and Indiana is indicated in each case.

Camarotoechia carolina.
Eunella sullivanti; Ontario, Canada.
Spirifer acuminatus; New York.
Spirifer grieri; New York.
Spirifer manni; New York.
Meristella nasuta; New York, Ontario, Nevada.
Crania crenistriata; New York, Michigan.
Craniella hamiltoniae; New York, Canada.
Chonetes acutiradiatus; New York.
Chonetes arcuatus; New York.
Chonetes vicinus; New York, Wisconsin, Nevada.
Pentamerella arata; New York, Ontario.

Among this list the following are cited from the Columbus limestone of Ohio, and from both the Jeffersonville and Sellersburg limestones at Louisville, Kentucky, or in Indiana.

Camarotoechia tethys; New York, Ontario, Nevada.
Cyrtina hamiltonensis; New York, Pennsylvania, Maryland, Ontario, Canada, Iowa, Nevada.
Spirifer fornacula; Illinois, Wisconsin.
Spirifer segmentum.
Spirifer varicosus; New York, Canada, Nevada.
Delthyris raricosta; New York, Maine, Ontario, Gaspe, Canada, Nevada.
Reticularia fimbriata; New York, Maryland, Virginia, Ontario, Canada, Illinois, Iowa, Nevada.
Nucleospira concinna; New York, Pennsylvania, Virginia, Ontario, Nevada.
Stropheodonta demissa; New York, Pennsylvania, Ontario, Canada, Illinois, Iowa, Tennessee, Wisconsin, Nevada.
Stropheodonta hemispherica; New York, Ontario.
Stropheodonta perplana; New York, Pennsylvania, Maryland, Maine, Illinois, Iowa, Wisconsin, Nevada, Ontario, Tennessee.
Pholidostrophia iowaensis; New York, Ontario, Illinois, Iowa, Michigan.
Chonetes mucronatus; New York, Ontario, Gaspe, Nevada.
Productella spinulicosta; New York, Canada, Michigan, Wisconsin, Iowa, Illinois, Nevada.

Rhipidomella vanuxemi; New York, Ontario, Michigan, Iowa, Illinois, Tennessee.

Among this list the following species are cited from the Columbus limestone of Ohio, and also from the Sellersburg limestone at Louisville, or in Indiana:

Tropidoleptus carinatus; New York, Pennsylvania, Illinois.
Spirifer duodenarius; New York, Ontario.
Spirifer macrus; New York.
Spirifer granulosus; New York, Pennsylvania, Maryland, Virginia, Michigan.
Roemerella grandis; New York.
Chonetes yandellanus.
Rhipidomella livia; New York, Ontario, Gaspe.

Among the species listed by E. M. Kindle as occurring in the Jeffersonville limestone of Louisville, Kentucky, and of Indiana, the following are not recorded from the Columbus limestone at Columbus, Ohio. The distribution outside of these States is added.

Rhynchonella gainesi-cassensis.
Rhynchonella depressa.
Camarotoechia congregata; New York.
Camarotoechia nitida.
Cyclorhina nobilis; New York, Ontario.
Cryptonella lens; New York.
Cryptonella ovalis.
Eunella harmonia; Ontario.
Eunella lincklaeni; New York, Michigan.
Cranaena romingeri; New York, Michigan, Iowa.
Terebratula jucunda; Iowa.
Atrypa ellipsoidea.
Cyrtina crassa; New York.
Spirifer davisi.
Spirifer gregarius-greeni.
Reticularia knappianum.
Reticularia wabashensis.
Meristella barrisi; New York.
Crania greeni.
Crania granosa; New York.

Stropheodonta plicata; Ontario, Iowa.
Orthothetes arctistriatus; New York, Pennsylvania, Canada, Nevada.
Chonetes subquadratus.
Productella semiglobosa.
Pentamerella thusnelda.
Camarospira eucharis; Ontario.
Gypidula romingeri-indianensis.

The following species are listed both from the Jeffersonville limestone and from the Sellersburg limestone, but are not recorded from the Columbus limestone at Columbus, Ohio:

Rhynchonella gainesi.
Rhynchonella tenuistriata.
Camarotoechia sappho; New York.
Cyrtina hamiltonensis-recta; New York.
Spirifer divaricatus; Canada, New York.
Spirifer gregarius; New York, Ontario.
Spirifer byrnesi.
Ambocoelia umbonata; New York, Pennsylvania.
Parazyga hirsuta; New York, Canada.
Athyris fultonensis; Missouri, Iowa, Michigan, Manitoba.
Pentagonia unisulcata; New York, Ontario.
Stropheodonta concava; New York.
Stropheodonta inaequistriata; New York, Ontario, Wisconsin.
Chonetes coronatus; New York, Pennsylvania, Ontario, Illinois, Wisconsin.
Schizophoria striatula; New York, Wisconsin, Iowa, Illinois, Missouri, Nevada, Canada.
Pentamerella pavilionensis; New York.

The following species, listed by E. M. Kindle from the Sellersburg limestone of Louisville, Kentucky, and of Indiana, are not recorded from the Columbus limestone, at Columbus, Ohio:

Glossina triangulata.
Rhynchonella louisvillensis.
Centronella glansfagea; New York, Ontario, Michigan.
Atrypa spinosa; New York, Pennsylvania, Maryland, Virginia, Ontario, Canada, Illinois, Iowa, Wisconsin.
Spirifer varicosus-hobbsi.

Spirifer arctisegmentum; New York.
Spirifer audaculus; New York, Wisconsin.
Spirifer iowaensis; Illinois, Iowa, Wisconsin.
Spirifer macconathei.
Spirifer pennatus; New York, Pennsylvania, Maryland, Virginia, Ontario, Wisconsin.
Delthyris sculptilis; New York, Pennsylvania, Ontario.
Martinia subumbona; New York.
Vitulina pustulosa; New York, Pennsylvania.
Athyris spiriferoides; New York, Pennsylvania, Maryland, Virginia, Canada.
Orbiculodea doria; New York, Ontario.
Crania sheldoni; Iowa.
Chonetes manitobensis; Canada.
Rhipidomella leucosia; New York, Maryland.
Rhipidomella goodwini.

A study of these lists suggests, in the first place, that there is a considerable similarity between the fauna of the Columbus limestone and that of the Jeffersonville and Sellersburg limestone. There is no strong evidence of the fauna in western Kentucky and southern Indiana having developed in a different basin from that occupied by the fauna of the Columbus limestone. Although the Cincinnati geanticline during the deposition of these limestones probably rose above the sea in north-central Kentucky and southern Ohio, there appears to have been free connection across the more northern part of the geanticline in central and northern Ohio and Indiana. This is indicated not only by the similarity of the two faunas on opposite sides of the Cincinnati geanticline, but also by the great outlier of Columbus limestone in Logan county, Ohio.

The Columbus limestone includes the faunas of both the Jeffersonville and of the Sellersburg limestone. Twelve species listed from the Columbus limestone are recorded only from the Jeffersonville limestone, seven are recorded only from the Sellersburg limestone, while fifteen are recorded as common to both formations. The fossils common to the Columbus limestone and both to the Jeffersonville and Sellersburg formations in general have a wider geographical distribution than those common only to the Columbus and Jeffersonville limestones, or to the Columbus and Sellersburg limestones. By far the greater

part of the species described from the Devonian limestones of Ohio, Indiana, and western Kentucky have a geographical distribution extending northeastward into New York, and Ontario. Parts of the fauna reach Virginia and Gaspe. Parts reach western Tennessee, Illinois, Michigan, Wisconsin, and extend northwestward into Canada. In general there appears no strong evidence of a western fauna entering this field from beyond the Mississippi. *Spirifer fornacula, Spirifer iowaensis, Terebratula jucunda, Athyris fultonensis, Crania sheldoni,* and *Chonetes manitobensis* are among the few fossils suggesting the presence of a northwestern fauna.

Even in Indiana, the faunas of the Jeffersonville and Sellersburg limestones are distinct only in the more southern parts of the State. About thirty-five miles north of Louisville, Kentucky, the two formations show a mingling of faunas, which becomes greater farther north. Under these conditions it is not strange that the Columbus limestone should show the elements of both the Jeffersonville and Sellersburg faunas.

Of the two formations recognized in Indiana, it is the Jeffersonville limestone which appears to extend in greatest development southward from Louisville to Lebanon, Kentucky, and thence eastward toward the eastern side of the Cincinnati geanticline. This is indicated by the great abundance of corals in the Devonian limestones of Lebanon, Kentucky, many of which are known from the lower part of the Jeffersonville limestone at Louisville. The brachiopoda from the vicinity of Lebanon include *Spirifer divaricatus, Spirifer fornacula, Spirifer varicosus,* and *Reticularia fimbriata,* listed both from Jeffersonville and from the Sellersburg limestone; and *Spirifer grieri, Spirifer manni, Pentamerella arata,* and *Eunella harmonia,* listed from the Jeffersonville limestone, corroborating the Jeffersonville affinities of the Lebanon fauna.

From Lebanon, Kentucky, the Devonian limestone may be traced readily to Junction City and eastward. In the Paleontology of New York, Vol. VIII, Hall and Clarke figure *Pentamerella arata. Spirifer fornacula* and *Reticularia fimbriata* occur in the lower part of the Devonian limestone at Duffin's cut, along the railroad, north of Junction City.

No attempt has been made as yet to study the fauna of the Devonian limestone, east of the Cincinnati geanticline, in Ken-

tucky. In the Paleontology of New York, Vol. VIII, Hall and Clarke describe *Crania favincola* from the Devonian limestone of Crab Orchard. *Pentagonia unisulcata, Athyris fultonensis, Spirifer varicosus* and *Spirifer byrnesi* are abundant at various localities near Crab Orchard. Corals are abundant and include many species. In his Kentucky Fossil Corals, published in 1885, W. J. Davis figures *Michelinia plana* and *Blothrophyllum zaphrentiforme* from Crab Orchard. In his contributions to Indiana Paleontology, published in 1898 and 1904, G. K. Greene records *Blothrophyllum houghtoni* and *Heliophyllum osculatum* from Crab Orchard. *Blothrophyllum cinctutum, Michelinia insignis, Favosites placenta,* and *Trachypora ornata* occur in this vicinity. The great abundance of corals suggests the presence of the Jeffersonville fauna here. There is a sufficient number of fossils here to determine the horizon definitely as soon as time can be found for careful collecting.

In the vicinity of Moberly, *Spirifer fornacula* occurs. Near Indian Fields, *Stropheodonta concava* and *Phacops rana* are found. Along the railroad, half a mile west of Clay City, *Reticularia fimbriata* is seen. The Devonian limestone may be traced from Crab Orchard northeastward as far as Olympia Springs, in Bath county. Both the Jeffersonville and Sellersburg faunas may be present in this area, but, at present, not enough is known to determine the horizon, although the numerous corals at some localities suggest the presence of the Jeffersonville horizon at least. In the absence of diagnostic fossils it is a waste of time to theorize, but these fossils can be obtained and eventually the relationship of these Devonian limestones of east-central Kentucky will be known.

The long gap between the exposures of Devonian limestone in Bath county, Kentucky, and Pickaway county, Ohio, a distance of almost 100 miles, prevents the use of any stratigraphic methods of determining the relationship of the Devonian strata of east-central Kentucky with those of Ohio. It is not unlikely that the Devonian areas of eastern Kentucky and of Ohio are connected, but the overlap of the Devonian Black shale probably has covered up the connecting belt of strata.

E. M. Kindle has correlated the Jeffersonville limestone with the Corniferous or Onondaga formation, and the Sellersburg limestone with the Hamilton formation of New York. The

Sellersburg limestone, however, contains a considerable admixture of Onondaga forms, although traces, at least, of the Hamilton fauna are discovered.

Fossils Cited by Linney from Devonian Limestones of Eastern Kentucky.

Linney correlated the Devonian limestones east of the Cincinnati geanticline with the Corniferous of New York. In his report on Lincoln county he cites from the waste of this limestone the following species:

Zaphrentis corniculum, Lesueur (=*Cyathophyllum corniculum*).
Zaphrentis gigas (=*gigantea,* Lesueur).
Zaphrentis rafinesquii, Edwards and Haime.
Cyathophyllum halli (=*Heliophyllum halli,* Edwards and Haime).
Phillipsastrea gigas, Owen.
Cystiphyllum americanum, Edwards and Haime.
Spirifer oweni (=*granulosus,* Conrad).
Spirifer umbonata (=*Ambocoelia umbonata,* Conrad).

From the Corniferous of Garrard county Linney cites:

Zaphrentis gigantea, Lesueur.
Zaphrentis proliferum (=*prolifica,* Billings ?).
Heliophyllum halli, Edwards and Haime.
Blothrophyllum decorticatum, Billings.
Cystiphyllum americanum, Edwards and Haime.
Phillipsastrea gigas, Owen.
Orthis vanuxemi (=*Rhipidomella vanuxemi,* Hall).
Spirifer oweni (=*granulosus,* Conrad).
Atrypa reticularis, Linnaeus.
Platyceras ventricosum, Conrad.

In the report on Clark county are cited:

Zaphrentis corniculum, Lesueur (=*Cyathophyllum corniculum*).
Heliophyllum halli, Edwards and Haime.
Phillipsastrea gigas, Owen.

From the Corniferous of Montgomery county Linney cites:

Zaphrentis gigas (=*gigantea*, Lesueur).
Zaphrentis proliferum (=*prolifica*, Billings ?).
Cyathophyllum halli (=*Heliophyllum halli*, Edwards and Haime).
Amplexus yandelli, Edwards and Haime.
Phillipsastrea gigas, Owen.
Strombodes knotti, Davis.
Cystiphyllum americanum, Edwards and Haime.
Favosites epidermatus, Rominger.
Favosites limitaris, Rominger.

From the Corniferous of Bath county Linney cites:

Zaphrentis proliferum (=*prolifica*, Billings ?).
Zaphrentis rafinesquii, Edwards and Haime.
Cyathophyllum gigas (=*Zaphrentis gigantea*, Lesueur).
Cyathophyllum juvene, Rominger.
Cyathophyllum halli (=*Heliophyllum halli*, Edwards and Haime).
Amplexus yandelli, Edwards and Haime.
Blothrophyllum americanum (=*Cystiphyllum americanum ?*).
Chonophyllum gigas (=*Zaphrentis gigantea ?*).
Phillipsastrea gigas, Owen.
Favosites limitaris, Rominger.
Favosites troosti, Edwards and Haime.

From the ore banks north of Preston in Bath county, where the Devonian limestone, the Corniferous of Linney, has been replaced in part by iron ore, Linney cites the following species:

Orthis vanuxemi (*Rhipidomella vanuxemi*, Hall).
Spirifer oweni (=*granulosus*, Conrad).
Spirifer raricostatus (=*Delthyris raricostata*, Conrad).
Spirifer umbonata (=*Ambocoelia umbonata*, Conrad).
Atrypa reticularis, Linnaeus.
Athyris spiriferoides, Eaton.

Spirifer granulosus and *Athyris spiriferoides* occur in the Sellersburg limestone in Indiana. *Delthyris raricostata*, *Am-*

bococlia umbonata, and *Rhipidomella vanuxemi* are found both in the Jeffersonville and Sellersburg beds. The preponderance of corals is noteworthy.

Variations in Thickness of Devonian Limestone in East Central Kentucky.

The Devonian limestone varies considerably in thickness. One of the thickest sections is exposed at the western end of Crab Orchard, north of the railroad, where it is nineteen feet thick. Two miles west of Crab Orchard, along the railroad, it is sixteen and a half feet thick. Two miles southwest of Crab Orchard, on the Chapel Gap road, it is eleven feet. Three and a half miles west of Crab Orchard, on the county road, it is eight and a half feet thick. Four miles west of Crab Orchard, on the Cox Gap road, the thickness is eleven and a half feet. About half a mile northwest of the last locality, it is six and a half feet. About a quarter of a mile farther west, the thickness may be five feet, but only two feet four inches are exposed. The same may be said of an exposure a quarter of a mile farther west. A short distance farther west, five miles from Crab Orchard, the clay resulting from the decay of the Devonian limestone suggests a thickness of only one foot. Farther west, as far as the Neal Creek church exposure, the Devonian appears absent. These observations indicate an irregular thinning of the Devonian limestone section from Crab Orchard westward as far as Neals Creek church.

Northwestward, toward Junction City, there is an irregular thickening of the Devonian limestone. At the Duffin cut, north of Junction City, the thickness is eighteen feet. Thick sections of Devonian limestone occur also southwest of Stanford. About five miles southwest of Hustonville, at the store owned by E. H. Kidd, the total Devonian limestone section has the remarkable thickness of forty-seven feet. Further study should be given this section, since here some of the layers poorly represented in the thinner sections are likely to be represented by thicker beds or by a series of layers.

East of Crab Orchard the Devonian limestone section appears to be thinner, the recorded measurements varying from

fourteen to fifteen and a half feet. But farther east, if the Devonian limestone were exposed, it might be found that thicker sections occurred again. The well record near Mullins Station, in Rockcastle county, suggests a thickness of twenty feet.

Another thick section of Devonian limestone occurs three miles southwest of Cartersville, where the road to Crab Orchard crosses the headwaters of Harmon creek. Here the Devonian limestone is seventeen feet thick. Half way between this locality and Crab Orchard the thickness of the Devonian limestone is only six feet, so that the Devonian limestone appears to become thinner from both areas toward this middle region. With the exception of the exposure near the headwaters of Harmon creek, the various recorded sections of the Devonian limestone between Lancaster and Berea vary from eleven to thirteen feet. Possibly the Devonian limestone thins out northward in this area, but if this is the case no evidence of such thinning has been discovered as yet, except along the railroad north of Berea. Here, directly north of Berea, the thickness of the Devonian section is thirteen and a half feet. Four miles north of Berea it is reduced to three inches.

Evidences of thinning are seen also in going from Berea northeast, toward Bobtown. In the vicinity of Bobtown, and from this region for at least three miles toward the east and northeast, the thickness of the Devonian limestone is reduced to about one foot or less, except at the Mat Moody store, a mile and a quarter toward the southeast of Bobtown. Here the thickness of the Devonian limestone is at least four feet four inches, again suggesting an irregular thinning of the Devonian limestone toward the north.

Farther northeast the Devonian limestone section thickens again. Between Berea and Brassfield it varies between five and seven feet. Near Rice Station it shows the remarkable thickness of twenty-one and twenty-three feet, in large part due to the introduction of great quantities of chert. Near Irvine the Devonian limestone sections do not appear to exceed eleven feet, but thicker sections are suggested by some of the well records east of Irvine.

Northwest of Rice Station several thick sections of Devonian limestone are known. West of Cobb ferry it is twenty-one and a half feet thick. A mile and a half farther west, at the head

of Falling branch, the thickness is at least eighteen feet. Southwest of Elliston it is nearly sixteen feet. These observations indicate a thinning of the Devonian limestone southwestward from Rice Station and Moberly toward Bobtown and Whites. Great variations in thickness are noted between Elliston and Cobb ferry. Near Waco the Devonian limestone does not exceed five feet.

Thick sections are exposed also near College Hill, and farther northward, on the road to Jackson ferry. At the more northern localities some of the measurements indicate thicknesses of seventeen feet and more.

Northeast of a line connecting Rice Station, Cobb ferry, and Jackson ferry, the thickness of the Devonian diminishes again. Near Vienna, measurements of eight and eleven feet are recorded. At Log Lick and northward the thicknesses vary between five and seven feet. Half a mile south of Indian Fields it is six feet. Locally it is less. A quarter of a mile south of Indian Fields, for instance, it is two feet and a half. Between Indian Fields and Clay City most of the sections of Devonian limestone vary between four and a half and seven feet, but about three and a half miles west of Clay City, between Hudson mill and Snow Creek church, there is a section in which the Duffin layer alone has a thickness of nine feet, and the underlying cherty Devonian limestone also is known to have considerable thickness.

A mile northeast of Indian Fields the thickness of the Devonian limestone varies between eight and ten feet. Between these localities and Spencer no sections thicker than three feet have been found so far, and between Levee and Jeffersonville are several localities where the thickness is less than two feet. At Spencer, sections nine and twelve feet thick are known. A mile south of Preston there is a section eight feet thick. Two miles east and west of this locality the thickness does not exceed three feet.

From the preceding observations it may be seen that the Devonian limestone varies considerably in thickness when traced along the line of outcrop in east-central Kentucky. In certain areas it appears to become thinner on approaching the Cincinnati geanticline, but if this thinning be general it is too irregular readily to be detected along the greater part of

the comparatively narrow belt of exposures. Possibly the alternate thickening and thinning of the Devonian limestones when traced along the belt of exposures is due to the former presence of a series of minor folds, subsidiary to the great Cincinnati geanticline, and more or less transverse to the eastern slope of the latter. A greater number of observations are needed to decide this matter. Possibly the records of wells bored for the purpose of securing oil may in the course of time yield valuable evidence. At present these records often are very misleading.

Minor Subdivisions of Devonian Limestone in East-Central Kentucky.

No careful study of the fauna of the Devonian limestone of eastern Kentucky has been attempted so far, nor has any attempt been made to determine how far the stratigraphic units present in different sections may be traced. Two layers, however, have attracted attention on the part of all observers, and will receive special consideration in the following discussion. One of these occurs at the base of the series of Devonian limestones, and the other is found at the top. The first is characterized by the presence of fish remains, the latter often has a brecciated appearance, and here is called the Duffin layer. The relative position of these layers may be indicated as follows:

Devonian or Boyle limestone...............	Duffin layer, usually several feet thick, often appearing brecciated.
	Limestone, sometimes richly fossiliferous and often cherty, usually forming by far the greater part of the Devonian limestone section.
	Kiddville layer, thin layer with fish remains.

The middle part of the Devonian section often contains great quantities of chert. This is true especially in the neighborhood of faults. In some localities, for instance near Rice Station, the quantity of chert exceeds the quantity of original Devonian limestone. At some localities, where the Devonian limestone is very thick, for this part of Kentucky, very little chert or none at all is found in the limestone, so that the distribution

of the chert appears to be quite irregular. All of this chert appears to be the result of segregation, most of the silica probably being derived from the decay of overlying strata, and being carried in by percolating waters. Where rocks were more or less brecciated, the opportunity for the accumulation of chert seems to have been much increased.

KIDDVILLE LAYER WITH FISH REMAINS.

At the Duffin cut, three quarters of a mile north of the railroad crossing at Junction City, the entire thickness of the Devonian limestone is fully eighteen feet. The lowest layer, two feet six inches thick, consists of dense, light grey limestone. One specimen of *Reticularia fimbriata*, and several large markings known as *Taonurus caudagalli*, occur near the base. Fish teeth are found within an inch of the base. Specimens of *Taonurus caudagalli*, occur also at higher horizons in the Devonian limestones of Kentucky. For instance, a little over two miles southeast of Crab Orchard, where the Devonian limestone is about fourteen feet thick, the lower part of the exposure, four feet thick, contains small *Spirifers* and other brachiopoda, while the immediately overlying layers contain the *Taonurus caudagalli* markings.

Four miles north of Berea, and half a mile south of White station, the Devonian limestone is reduced to only three inches in thickness, consists of blue, argillaceous, gritty limestone, and contains fish remains. A mile and a half farther south, the layer with fish remains is only one inch thick; but it is overlaid by Devonian limestone, two feet four inches thick, and by the cherty Duffin layer, which was not measured. Nearer Berea the total thickness of the Devonian limestone is thirteen feet six inches. At the localities between Berea and Whites there are found both fish teeth and the tuberculated plates, which have been referred by Linney and Knott to *Macropetalichthys*, but which have not been carefully studied as yet by those conversant with fossil fish faunas. In the area extending from the locality half a mile south of Whites station to the localities about three miles almost directly east of Bobtown, the thickness of the Devonian limestone frequently is less than one foot. At the most eastern locality in this area, at the headwaters of

Drowning creek, it varies between two and six inches or may be entirely absent; traces of fish remains are found.

A mile and a half east of Moberly, on the western side of Muddy creek, southwest of Elliston, the thickness of the Devonian limestone appears to be fifteen feet eight inches. The lowest layer consists of gray, well-bedded, sandy limestone, two feet thick, overlaid by an equal thickness of similar rock; between these layers of limestone there is a thin film of rock containing fish teeth and small black nodular particles. Wherever these nodular particles occur, careful search will usually result in the discovery of fish remains, and in this connection, therefore, it is of interest to note that in the area between Whites and the localities three miles east of Bobtown, where the thickness of the Devonian limestone is so much reduced, the black nodular particles are rather common, and the rock is decidedly sandy.

Along the exposures extending from a quarter of a mile south of Indian Fields up a small stream to the rear of the home of John Goff, the layer with fish remains, both teeth and tuberculated plates, occurs. Directly south of Indian Fields, the layer containing fish remains is about a foot thick, and quite sandy. The total thickness of the Devonian limestone is about two and a half feet. North of the home of John Goff the Devonian limestone section is fully six feet thick. The lowest layer, five inches thick, contains fish remains and the tiny black nodular particles. The overlying layer of ferruginous brown limestone, eleven inches thick, contains fish plates. This is followed by sandy rotten stone, one foot six inches thick. About a mile east of Indian Fields, at the Hollywood or Stuart mill, where the Devonian limestone is ten feet thick, the lowest layer consists of reddish brown limestone, four feet four inches thick, with *Phacops rana*. This layer is believed to correspond to the reddish brown limestone with tuberculated fish plates found north of the home of John Goff. Above this horizon at the Hollywood locality is found a sandy rock, one foot nine inches thick, containing the tiny black nodules and the fish remains. Half a mile southeast of the Hollywood mill, at the spring north of the home of Will Lawrence, north of the oil spring, fish remains occur at the base of the Devonian section, in a crumbling layer four inches thick. The overlying massive limestone, three

feet four inches thick, is believed to correspond to the layer with tuberculated plates occurring north of the home of John Goff. The overlying layer is one foot three inches thick, and is shaly rock. The total thickness of the Devonian limestone here is nearly nine feet. A mile and a half southeast of Indian Fields, at the Eastin mill, and several miles down stream at the Abbott mill, the fish layer occurs again, at the base of the Devonian limestone. It is found at the base of the Devonian limestone also half a mile west of the bridge at the western end of Clay City, along the railroad; two miles southwest of Clay City, at Tipton Ferry; at both localities in sandy limestone about half a foot thick.

About a mile south of Preston, east of a small branch entering Mill creek from the west, the thickness of the Devonian limestone is fully eight feet. The layer with fish remains occurs at the base of the Devonian section and is only three inches thick. A magnificent exposure of the layer with fish remains occurs about a mile west of Preston, along the railroad.

Eight miles east of Owingsville, in the extreme western part of Rowan county, northwest of Moore's ferry, a layer of limestone, thirteen inches thick, containing *Taonurus caudagalli*, occurs at or near the base of the Devonian black shale. The rock has a grayish color and apparently belongs to the base of the Black shale series rather than to the Devonian limestone series of more southwestern exposures in Kentucky.

In the Linney reports on the geology of the various counties bordering central Kentucky, the layer with fish remains is referred to the Oriskany. In his report on Lincoln county the following section is published from a locality above the junction of Flax or Flades creek with Dix river, described in descending order:

Heavy corniferous limestone layer	33 in.
Covered space	12 in.
Drab sandstone	12 in.
Rock weathering to olive shale	16 in.
Sandstone with *cauda-galli* fucoids	3 in.
Sandstone with *cauda-galli* fucoids	20 in.
Magnesian limestone	2 in.
Magnesian limestone	27 in.
Crab Orchard shale.	

The magnesian limestone at the base of the section is said to contain a *Spirifer* two and a half inches in length. This *Spirifer* must be one of the Devonian species, no *Spirifer* of this description being known in the Silurian of Kentucky or neighboring States. The large *Spirifer* mentioned by Linney may be the same as a species three and a half inches in length along the hingeline which occurs at the western end of Crab Orchard, north of the railroad, about three feet above the base of the Devonian limestone. Unfortunately, no attempt was made to cut the specimens out of the rock and therefore the species can not be identified at present. The layers with *Taonurus caudagalli* occur two and a half feet above the base of the Devonian according to the published section. There can hardly be any question of the Devonian age of the magnesian limestone layers in the Linney section in view of the fact that near the home of Mr. Howard, north of the railroad, two miles east of Crab Orchard and only a mile and a quarter southeast of the locality describtd, there is an exposure at which layers containing *Taonurus caudagalli* are underlaid bv limestone four feet thick, containing undoubted Devonian brachiopods. The so-called sandstones of Linney's section are gray limestones. These he correlates with similar rocks at the base of the Devonian section in Boyle and Marion counties containing spines, teeth, and plates of large fishes. The tuberculated plates he identifies with the genus *Macropetalichthys*, and states that the rocks here described might represent both the Oriskany sandstone and the *Cauda-galli* grit of New York.

In the report on Clark county, Linney refers to the Oriskany a layer of stone about one foot thick, nearly white where exposed in the bed of creeks, but of a rather dull, dirty blue when broken, containing in the lower part bones, spines, plates, and teeth of fishes, most of which had been ground into pebbles before they were left to be consolidated into rock. Some of the small teeth, however, are whole, and the tubercles on some of the plates are well preserved. At some localities the layer with fish remains is chiefly a limestone; at others it contains enough silicious matter to rank as a sandstone. The presence of the single layer of rock containing fish remains and *Taonurus cauda-galli* is noted also in the report on Montgomery county, under the name Oriskany sandstone. In the report on Bath

county the layer with fish remains is stated to be present in Marion, Boyle, Lincoln, Garrard, Madison, Clark, Montgomery, and Bath counties. It is described as consisting usually of a single layer of dirty, bluish grey, tough stone, containing sand, lime, and alumina, and marked by *Taonurus cauda-galli*. In the lower part, at nearly every exposure, it contains quantities of the remains of bones, fins, and teeth of fish, with phosphatic nodular masses which may have been the excrement of the same form of life. Rarely a few casts of shells are seen, among others, a well preserved cast of *Conularia*. This layer usually has a thickness of twelve to eighteen inches, but at some points in Bath county, according to Linney, rises to a thickness of about three feet.

DUFFIN LAYER.

In the report on Lincoln county, Linney describes the Duffin layer as follows. In Lincoln, and to some extent in Boyle county, there is to be seen a very peculiar rock, varying from two inches to twelve feet in thickness, at times having very much the appearance of a breccia. This rock has a massive gray base, and at some localities apparently fragments of a brown rock are distributed through it irregularly. At other localities, the brownish particles do not appear to have resulted from brecciation, but from the alteration of fossils. It is doubtful whether any part of this rock is brecciated. The layer is well exposed in the railroad cut near McKinney's station and in the cut near Junction City, on the edge of Boyle county. A fragment sent to Dr. Robert Peter was described by him as a dark gray, fine-grained rock, mottled with whitish and light-yellowish gray spots of various sizes and shapes; containing small cavities, some lined with small quartz crystals, some filled with calcite and containing semi-opal. The rock contains bituminous matter, the irregular infiltration of which has caused some of the mottling. In the report on Garrard county, the Duffin layer is described as appearing as though it had been made of the broken, angular pieces of some rocks, cemented in a base having another shade of color, but Linney states that he found it impossible to determine whether the rock was a true breccia, or whether the brecciated appearance resulted

from the alteration and removal of fossils. In the report on Clark county, the Duffin layer is called the brecciated layer. In the report on Montgomery county it is stated that the layer resembling a breccia is rarely seen. No mention is made of the Duffin layer at any of the localities farther north.

The typical exposure occurs at the Duffin cut (See Fig. 2, Plate 8), three quarters of a mile north of Junction City. Here the Duffin layer forms the top of the Devonian limestone section. The rock weathers to a brownish color, and the weathered surface shows some small quartz concretions. The layer contains a few crinoid stems and corals, and also some fucoidal markings. It is six feet thick, the thickness of the entire section of Devonian limestone being about eighteen feet.

About six miles east of Junction City, and three and a half miles northwest of Stanford, the Duffin layer is nearly six feet thick. About a mile west of Stanford, at the Buffalo spring, the Duffin layer is at least five feet thick, and the Devonian section is at least eleven feet thick. Thirteen miles southeast of Stanford, on the Cox Gap road, the top of the Devonian limestone has a brecciated appearance. A little over two miles west of Crab Orchard, along the railroad, the thickness of the Duffin layer is two and a half feet. At the western end of Crab Orchard, north of the railroad, the brownish rock, considered equivalent to the Duffin layer, is eight inches thick. Similar rock is poorly exposed at the home of Bill Monk, a little over a mile southeast of the railroad station at Crab Orchard, north of the railroad. A mile and a quarter north of the center of Crab Orchard, on the Lancaster road, the Duffin layer is four inches thick.

About three miles northeast of Crab Orchard, and a quarter of a mile south of Fall Lick creek, the Duffin layer is four inches thick. About two and a half miles south of Hammack, south of Harmon creek, the thickness of the brownish rock, which may represent the Duffin layer, is one foot. Beneath this rock is a thin streak of black shale, overlying, in descending order, limestone, six feet thick; soft rock, weathering back, five and a half feet thick; and bluish argillaceous rock, four and a half feet thick; a total of seventeen feet of rock belonging to the Devonian limestone section. Two miles southeast of Hammack the Duffin layer is eight feet thick; two miles north-

west of Hammack, on the road to Point Leavell, it is five and a half feet thick; three and a half miles southeast of Lancaster, on the road to Hammack, it is five and a half feet thick. Three quarters of a mile east of Cartersville, where the rock is much disturbed, the thickness appears to be eleven feet, and seems to include all of the Devonian limestone at this point. Two miles northeast of the last locality, near the home of Charles Baker, the Duffin layer is four feet thick, and the entire thickness of the Devonian limestone appears to be about eleven feet. About a mile east of the last locality, three miles southwest of Berea station, the Duffin layer is five and a half feet thick; it contains fragments of crinoid stems and cyathophylloid corals. The total thickness of the Devonian limestone is twelve and a half feet.

Half a mile north of Berea station the Duffin layer is five feet thick. It is exposed again about a mile farther north. Brecciated appearing rock occurs near the bridge over the railroad at Brassfield; it is a foot and a half thick, the total thickness of the Devonian limestone being seven feet. Three quarters of a mile southwest of Rice Station the Devonian limestone section appears to be twenty-three feet thick; at the top is a brownish layer, four feet thick, which appears to be equivalent stratigraphically to the Duffin layer. Nearer Rice Station this brownish limestone is only one foot four inches thick.

East of Moberly, immediately southwest of Elliston, the Duffin layer is two and a half feet thick. West of Cobb ferry the Duffin layer has the brecciated appearance, is five feet thick, and contains fragments of crinoid stems and *Favosites,* with some chert at the base. Three miles north of College Hill, where the Devonian limestone section is fully twenty feet thick, a brownish layer of rock, which may be the equivalent of the Duffin layer, appears at the top of the section. It is one foot thick, and separated by black shale, nine inches thick, from brownish rock, three feet thick, containing abundant specimens of *Taonurus caudagalli.* The top of the cherty layers is one foot three inches lower down. The layer with *Taonurus caudagalli* found in the extreme western part of Rowan county probably is to be correlated with this upper *Taonurus* horizon rather than with the lower horizon, near the base of the series of Devonian limestones, near Crab Orchard.

Three quarters of a mile southeast of Vienna, near the home of James Stone, the Duffin layer is five feet thick. Southwest of Vienna, near the home of Old Jones Finnell, the top of the Devonian limestone section consists of hard brown limestone, five feet three inches thick, underlaid by brecciated appearing rock, one foot thick; soft rock, one foot thick, and cherty limestone, six feet thick. This position of the brecciated appearing layer is unusual. Near Log Lick church the Duffin layer is two feet thick. A mile northward, at the J. T. Elkins locality, it is replaced by argillaceous rock, three feet thick. Between Arlen and Rightangle the Devonian exposures are five feet thick; the greater part of the rock has a brecciated appearance, but the lower part, eighteen inches thick, contains considerable chert. Three and a half miles west of Clay City, on the road from Hudson's mill to Snow creek church, the argillaceous rock at the top of the Devonian limestone section is nine feet thick, contains Devonian brachiopods, and appears brecciated only at the base, in this respect resembling the exposure southwest of Vienna.

The Duffin layer is exposed northwest of Indian Fields, along the railroad. At the oil spring, southeast of the hotel, about a mile northeast of Indian Fields, the brecciated appearing layer is one foot thick and is separated from the underlying solid, light brown limestone by black shale, two inches thick. The overlying rock, ten inches thick, is similar in general appearance, but does not show the brecciated feature; farther up, the rock is more shaly and graduated into the black shale series. At the Hollywood or Stuart mill, the Duffin layer is one foot eight inches thick. At the spring near the home of Will Lawrence, it appears to be nearly four feet thick. East of Spencer, west of Slate creek bridge, the Duffin layer is one foot six inches thick and is overlaid by brownish limestone, four feet three inches thick, which does not have the brecciated appearance. About a mile south of Preston, east of a small branch entering Mill creek from the west, the top of the Devonian limestone section consists of brownish rock, two feet six inches thick, with traces of the brecciated appearance.

The list of localities here given is sufficient to show the very general distribution of the Duffin layer. During the progress of the field work it was noted that the Duffin layer sometimes

presented the brecciated appearance and sometimes not. Unfortunately, the recorded notes do not indicate with sufficient exactness the degree of brecciation suggested by different exposures, nor attempt a very exact correlation of the brecciated appearing layer with those not showing this feature, but which probably belong to the same horizon. Hence one of the series of observations necessary for a solution of the problem as to the brecciated appearance of the Duffin layer is not at hand. Careful study does not warrant the opinion that the small angular appearing particles, seen in the otherwise homogeneous appearing rock, are fragments of some earlier rock, broken up and washed in from some outside source. As far as present observations go, the brecciated appearance is seen best near lines of faulting, though present in rocks at some distance from faults.

Possibly, in the processes of folding and faulting, long after the deposition of the overlying rocks, there was a slight shifting of layers over one another. Such a shifting of layers may have caused the contorted appearance of certain layers in the Cynthiana or Point Pleasant formation, in the Garrard bed, and in the so-called mudstones (Tate) of Mason county, belonging to the Fairmount bed. In the case of the Duffin layer this motion of layers over one another may have resulted in an irregular distribution of pressures within the rock, which at first did not reveal itself in any manner, neither by a system of cracks nor by differences of color. But in the course of time certain particles were affected slightly differently chemically than others, this difference finally leading to the differences in color now observable between the apparent fragments and the enclosing general body of the rock. It must be acknowledged, however, that it is difficult to determine how such an interpretation can be made to explain the differences in chemical composition shown by the analyses furnished by Professor Peter, since, according to these analyses, the proportion of silica and alumina is twice as great, and the proportion of ferrous iron is less, in the gray component of the Duffin layer than in the white component, while the proportion of other ingredients is about the same.

THE DEVONIAN BLACK SHALES.

Near Columbus, Ohio, and northward, the Ohio black shale is underlaid by the greenish Olentangy shale. In the northern part of that State the Ohio shale is divided into the following subdivisions, named in descending order:

Cleveland shale,
Chagrin formation,
Huron shale.

Until more is known of the paleontology of these divisions in northern Ohio, it is idle to attempt to determine whether the Devonian black shale of Kentucky includes elements of all three of these subdivisions or whether it is to be correllated with only one of them. There is no doubt of the rapid decrease in thickness of the Black shale formation on going southward into Kentucky. It is stated by Prof. Charles S. Prosser that the top of the Ohio shale in southern Ohio corresponds with the top of the Cleveland shale, and that Andrew's Ohio shale is equivalent to the Huron, Erie (Chagrin formation), and Cleveland shales of Dr. Newberry in northern Ohio. This statement suggests a similar view of the Devonian black shale, at least in northern Kentucky. Farther southward, where the shale becomes more attenuated, it is probable that one or more of these divisions, or, at least, considerable portions of them, may be found absent.

VARIATIONS IN THICKNESS OF BLACK SHALE.

South of Lebanon, the thickness of the Devonian Black shales is forty-one feet. At Junction City, southwest of the Duffin cut, the aneroid barometer indicated a thickness of about sixty feet, but this instrument is known not to be strictly reliable. Two and a half miles west of Berea the recorded measurements indicate a thickness of eighty-five feet, but there is no means, at present, of determining the amount of dip. South of Indian Fields the thickness is 127 feet. Northeast of Indian Fields, about a mile, the thickness is 125 or 130 feet.

The well records in Powell county suggest thicknesses of 125 to 135 feet. The well records in Menefee county indicate thicknesses varying from 135 to 160 feet. In the extreme eastern

edge of Bath county, in the Ragland field, even greater thicknesses are indicated. From the records of about fifty wells, J. B. Hoeing estimates the average thickness of the Devonian black shale at 205 feet.*

Mr. Hoeing gives the following estimated thicknesses of the Devonian black shale on going from Bath county westward, these estimates being derived from the outcrops:*

Bath county	135 ft.	
Montgomery county	110 ft.	
Clark county	100 ft.	
Powell county	100 ft.	
Estill county	100 ft.	
Garrard county	50 ft.	Estimate too small.
Marion county	60 ft.	
Nelson county	50 ft.	
Larue county	65 ft.	
Bullitt county	70 ft.	
Jefferson county	100 ft.	

These estimates indicate a general thinning of the Devonian Black shale southward. From Marion county this southward thinning continues as follows:

Marion county	60 ft.
Casey county	45 ft.
Russell county	40 ft.
Clinton county	30 ft.
Cumberland county	25 ft.
Monroe county	20 ft.

This thinning of the Black shale continues southwestward through Tennessee. Along the Harpeth river, southwest of Nashville, the thickness is about twenty feet. Farther south the measurements usually vary between five and eight feet, and in some of the more southern areas the Devonian black shale is entirely absent.

The Devonian black shale thins also westward. Mr. J. B. Hoeing, however, publishes certain measurements secured from well records, which, if corroborated by the diamond drill, indicate a thickening of a very unexpected kind west of the Cincinnati geanticline, in Kentucky at least. These records are as follows:*

* The Oil and Gas Sands of Kentucky, Kentucky Geological Survey, Bulletin No. 1, 1904.

Breckenridge county	95 ft.
Hart county	105 ft.
Warren county	90 ft.

When it is considered that in the neighborhood of Cumberland City, in northwestern Tennessee, the Devonian black shale is only about ten feet thick, and that in western Illinois, in Jersey county, north of St. Louis, only traces are left, the importance of these statements by Mr. Hoeing will be evident. In some parts of Union county, in southern Illinois, Black shale, fifty to seventy feet thick, is recorded by Worthen.

In the "Fluor Spar Deposits of Southern Illinois," published in 1905, H. Foster Bain states that the Black shale near Hicks, in Hardin county, Illinois, the third county east of Union county, is at least fifty feet thick, and that probably one hundred feet or more are present.

Nothing is known at present of the thickness of the Devonian black shale in the area between southern Illinois and Breckenridge, Hart, and Warren counties, in Kentucky.

The Black shale is the great knob formation of Kentucky. All around the Ordovician and Silurian area of central Kentucky it produces the numerous steep rounded hills here known as the knobs. The abrupt change from the fertility of the Ordovician and Silurian areas to the comparative barrenness of the knobs is noticed even by the most careless observer. In Ohio, drain pipes have been burned from the clays resulting from the decay of the Black shale. At some localities a deep red brick has been obtained.

BASE OF BLACK SHALE SECTION.

Sandy rock, six inches thick, appears at the base of the Black shale section, five and a half miles southwest of Berea station. At Abbott's mill, two and a half miles south of Indian Fields, the top of the Devonian limestone shows worm borings. North of the home of John Goff, half a mile south of Indian Fields, a sandy rock with worm borings appears at the base of the Black shale section.

At some localities a thin streak of Black shale is seen between a layer of brownish rock, believed to belong to the Duffin horizon, at the top of the Devonian limestone section, and the

immediately underlying main body of Devonian limestones. Such a section may be seen five and a half miles northeast of Crab Orchard, along the headwaters of Harmon creek. Another exposure occurs three miles north of College Hill, where the road to Union City turns off toward the southwest. At the Oil spring, southeast of the hotel, a mile northwest of Indian Fields, a layer of black shale, two inches thick, occurs beneath the strongly brecciated appearing layer; the underlying part of the Devonian limestone at this locality is only fourteen inches thick. The section a hundred yards northeast of the hotel is quite different in appearance.

At quite a large number of localities, the base of the Black shale series, instead of being very black, and fissile, is dark gray in color, at least when weathered; it is more indurated, less fissile, less carbonaceous, less fine-grained, and breaks in more irregular lumps. This more argillaceous phase at the base of the Devonian Black shale is only four inches thick four miles southwest of Berea. Similar rock occurs at the base of the Black shale series one mile south of Bobtown. A mile and a quarter southeast of Bobtown, at Mat Moody's store, it is one foot four inches thick. Half a mile north of Mat Moody's store it is four feet thick. Two and a half miles north of the store it is two and a half feet thick. Three miles east of Bobtown the argillaceous rock is four feet thick, and is separated from the underlying Devonian limestone by a thin streak of Black shale. West of the railroad station at Irvine, argillaceous rock occurs in the lower six feet of the section. The lower part of the Black shale series is more indurated, and has a grayish color immediately west of Rice Station and, again, three quarters of a mile farther west.

South of Waco, the Devonian limestone is overlaid by grayish, more indurated rock, one foot three inches thick; black shale, six feet three inches thick, with a grayish indurated layer in the middle; and another indurated argillaceous rock layer, six inches thick, followed by the great mass of fissile black shales. A mile and a quarter northeast of Waco, at the Moore Spring, the Devonian limestone is overlaid by argillaceous indurated grayish shale, eleven feet six inches thick; more solid argillaceous shale, three feet thick; softer argillaceous shale, three feet thick; more solid argillaceous, grayish rock, nine

inches thick; graduating into the fissile black shale above. This is the thickest section of indurated clay rock and irregular more massive grayish shale known at the base of the Black Shale section. A part of this indurated shale resembles considerably some of the so-called Waverly shales in southern Kentucky, where this part of the section is not represented by soft clays, but by more indurated clay shales or shaly rocks. Somewhat similar shaly clay rocks occur three miles north of College Hill.

Three and a half miles west of Clay City, between the Hudson mill and Snow creek church, argillaceous clay rock, nine feet thick, occurs at the base of the Black shale series; the lower part is brecciated, the argillaceous rock gradually merging into the brecciated base. Northeast of Indian Fields, at the spring near the home of Will Lawrence, lenticular layers of the clay rock appear in the lower part of the Black shale series, and are overlaid by the main body of fissile black shales. At the Eastin mill, farther north, the lower part of the Black shale series consists of black shale interbedded with more or less clay rock.

A mile southwest of Jeffersonville, a hard argillaceous rock layer appears five and a half feet above the base of the Black shale; the underlying part of the Black shale series has the usual black color. Similar rock is found in the lower part of the Black shale series northwest of Jeffersonville.

From the preceding notes it may be seen that in many parts of east-central Kentucky the Devonian Black Shale series begins with a lighter colored and more massive rock, varying from a few inches to a few feet in thickness. It is less impregnated with carbonaceous matter and not so fine grained as the black fissile shales forming almost all of the remainder of the Black shale section.

West of Rice Station, the top of the Devonian limestone is overlaid by shale, some of it black, and some more gray in color and more indurated. The thickness of this basal part of the Black shale section varies between thirteen and eighteen and a half feet. Overlying this is a solid argillaceous limestone, two feet thick, containing Devonian cyathophylloid corals, *Atrypa reticularis*, and other shells not collected or identified. Clayey layers occur interbedded in the overlying part of the Black shale series for a distance of about seven to ten feet. In some cases these clayey layers are indurated into clay rock.

According to the well records, in the eastern part of Bath county, the hard Devonian limestone is overlaid by about twelve feet of rock described as a brown shale, and this, in turn, by clayey material, six to eight feet thick, described as white fireclay. The interpretation of this part of the section requires further study. In the meantime it may be of interest to note that greenish clay shale, five and a half feet thick, occurs at various localities along Fox creek, in the eastern part of Fleming county. It is well exposed between Fox Spring and Muse's Mills. In this case it is underlaid by massive rock, crinoidal in part, decreasing in thickness from nine feet at the Fox Spring to three feet at the Muse's Mills. Underlying this limestone, the age of which has not been determined, is the top of the Crab Orchard clay section.

NOTES BY LINNEY ON THE DEVONIAN BLACK SHALES.

Linney states in his report on Lincoln county, that in instances limestones are formed locally in the Black shale. The surfaces of some of the plates are wave-marked. The base of the section, in some places, contains quartz grains. Iron pyrites is common throughout the entire series. Sea-plant impressions are common features at some horizons. That the Black shale is bituminous, and that efforts have been made at various times to secure oil and coal from it is well known. In the report on Garrard county Linney states that two inches of worthless asphaltum coal were noticed not far from Dripping Springs. At the base of the Black shale here there occur some rounded grains of transparent quartz sand. Higher up, patches of yellow sand are seen, and marks of plants are not uncommon. Small species of *Lingula* and *Discina* are often found. The Black shale finds very extensive use as a road ballast, and forms good roads, especially during the summer time. In the report on Clark county Linney alludes to the presence of oil in springs issuing from the Black shale, due to the bituminous material in the shale; also, to the frequency with which copperas occurs, due to the destruction of the iron sulphide, or iron pyrites, so abundant in some sections.

Along Copperas creek, near the junction of Clark and Powell counties, very exceptional conditions were noted. Only a few

feet above the base of the Black shale series, interbedded with the Black shale, occurs locally a layer of stone, distinctly wave-marked. Five feet farther up occurs a layer of phosphatic sandstone, two inches thick. This layer is composed of small rounded grains of hyaline quartz, and contains fragments of spines, teeth, and bones of small fishes. A few feet farther up occurred a layer of clay, ten or twelve inches thick. The immediately overlying layers of slate for several inches were covered with the impressions of several species of plants. Some of these were land plants of the genus *Lepidodendron*. Several feet farther up there was seen at several places a layer of crystallized dolomite, two inches thick. At another locality, sandy concretions, over a foot thick, were found. At still another locality there was a thin layer of asphaltum coal. At one locality on Copperas creek, only a few hundred yards from Eastin's mill, there is a larger amount of iron pyrites in the Black shale than at any other known locality in the field. Its decay gives rise to copperas in such quantities that no fish, cray-fish, worm, or bug is seen in its waters.

In the report on Bath county, Linney emphasizes the barren character of the soils produced by the decay of the Black shales. The shale breaks up into thin, fissile, ash-colored fragments when exposed for a long time. These crumble into small thin plates, that creep down steep slopes, and leave the hillsides almost bare of earth. These particles weather into cold, stiff clays, forming poor soils. Attention is called to the mineral springs caused by the decomposition of the materials in the Black shale. Near Young's Springs, and at several other places, were seen two layers of blue clay, sixteen to twenty-four inches in thickness, which are regarded as possibly the thin southern equivalent of the Erie shale of Ohio. In the earlier part of this bulletin, the Erie shale is called by the name introduced by Professor Prosser, of the Ohio Geological Survey, the Chagrin formation. If this identification by Linney can be established, the measured sections near Indian Fields suggest a thickness of seventy-five to eighty-two feet for the Huron shale; five and a half to fifteen feet, a very indefinite amount, for the Chagrin formation; and thirty-five to forty feet for the Cleveland shale. According to this interpretation, the huge fish remains on Copperas creek should fall within the Huron shale, but these local-

ities have not been visited, and therefore the position of the fish remains with reference to the clay layers here discussed can not be certified.

In the report on Fleming county, Linney states that the blue clay shales identified with the Erie shales (Chagrin formation) appear to have increased in having come northeast from Bath county.

Greenish Clays Above Middle of Black Shale Section.

The Black shale section usually consists of an almost uniform series of thin, black, fissile shales. At some localities, however, a few thin soft greenish clay layers are intercalated at various intervals. North of the home of John Goff, half a mile southwest of Indian Fields, several of these layers, eight inches thick, are interbedded with the Black shales, between eighty-two and eighty-eight feet above the base of the section. Similar greenish clay layers occur between ninety and one hundred and five feet above the base of the Black shale section, west of the Oil Springs Hotel, northeast of Indian Fields. Along the road between Indian Fields and Clay City, these greenish, soft clay layers intercalated with the Black shales are exposed by the creek along which the road passes.

West of Rice Station, along the railroad between Richmond and Irvine, copperas oozes out of the Black shale, sixty feet above the base of the section. The greenish clays noted between Indian Fields and Clay City should occur farther up.

Greenish clays are exposed at quite a large number of localities in the Black shale section, but it has not been determined, as yet, even whether these clays are found at approximately the same horizon or not. The chief interest in these clays lies in the possibility of their being southern representatives of the Chagrin horizon of northern Ohio. At present there is no evidence in favor of such an interpretation. Several notes on these clays are recorded in the preceding section of this bulletin.

Phosphatic Nodules at Base of Waverly Section.

At the top of the Black shale section, forming the base of the Waverly series, phosphatic nodules, light gray or purplish in color, are widely distributed. Near Junction City these

nodules often are two and three inches in length, are very abundant, and, although most abundant at the very base of the Waverly series, occur also one or two feet above the same. Farther northeast, these nodules usually are smaller, less abundant, and occur only at the very base of the Waverly. Five and a half miles southwest of Berea station these nodules are one to two inches in length. Small phosphatic nodules occur at the top of the Black shale series also northwest of Indian Fields, on the top of the hill crossed by the road to the Oil Springs. Two and a half miles southeast of Levee, there appears to be a continuous layer of this purplish phosphatic rock, varying between a foot and a foot and a half in thickness. Nothing similar has been found anywhere else in the field. Along the Cumberland river, in southern Kentucky, these phosphatic nodules often are four inches in length, and sometimes attain diameters of six, and even eight, inches.

The phosphatic nodules often are fossiliferous. A considerable fauna could be collected by cracking open great numbers of them, and at some localities these nodules are very abundant.

Phosphatic deposits usually suggest segregation during a period of weathering and erosion. The base of the Devonian limestone section often contains considerable phosphatic material, more than is accounted for by the presence of the fish teeth and scales. In that case a period of erosion preceding the deposition of the Devonian limestone is easily credible, considering the distinct unconformity between the base of the Devonian limestone and the top of the underlying Silurian clays and limestones. But in the case of the phosphatic nodules at the base of the Waverly, such an unconformity has not been made out as yet.

From the phosphatic nodules at Junction City the following crustaceans have been described: *Ceratiocaris (Colpocaris) bradleyi*, *C. elytroides*, *Ceratiocaris (Solenocaris) strigata*, and *Archaeocaris vermiformis*; all by Meek.

FOSSILS OF THE DEVONIAN BLACK SHALES.

In the Report on the Geology of Lincoln County, published in 1882, Linney states that *Dadoxylon newberryi*, Dawson, part of the trunk of a large species of tree, is represented by many remains in a silicified condition, in Lincoln and neighboring

counties. In addition to this are mentioned *Discina, Lingula,* and other shells; fish remains, including spines of *Ctenacanthus.* The presence of *Lingula* and *Discina* in the Black shales is mentioned again in his report on Garrard county. Linney notes the presence of *Dadoxylon newberryi,* Dawson, also in Clark county.

In the report on Clark county, published in 1884, Linney refers to a layer containing *Lepidodendron* in the Black shale series, along Copperas creek, near the junction of Clark and Powell counties. His statements on the stratigraphical position of this plant bed have been quoted in the immediately preceding part of this bulletin. In addition to *Lepidodendron*, as identified by Linney, this layer, several inches thick, contains also leaves eight to ten inches long, said by Linney to resemble our common flags. These plant remains occur in immense numbers. Above these layers, and in one instance also below, were scattered nodules in a very promiscuous manner. These consisted of accretions of fossils replaced by iron pyrites. Among these fossils the genera *Bellerophon* and *Orthoceras* were identified. Two feet farther up were found the remains of two individuals of a very large fish, imbedded in the Black shale. These remains were identified by Linney with *Dinichthys hertzeri,* Newberry, on the basis of two dorsomedian plates, nearly two feet in diameter, one of these more perfect than the plate figured by Newberry in the Ohio report. Another, much more massive bone, could not be identified. These fish remains are now the property of the Kentucky Geological Survey, and are exhibited in the Museum.

Dinichthys hertzeri occurs in the Huron shale, the lower part of the Black shale series of Ohio. *Dinichthys terrelli,* the large plates of which were at first included under the name *Dinichthys hertzeri,* occurs in the upper part of the Cleveland shale, the upper part of the Black shale series of Ohio. In addition to *Dinichthys terrelli,* the Cleveland shale contains the smaller species, *Dinichthys intermedius, D. curtus,* and *D. goulai;* and still smaller species, *Dinichthys corrugatus* and *D. minor*, have been published. It is not known at present whether the large plates of fishes discovered by Linney on Copperas creek occur above or below the horizon containing interbedded layers of greenish clay, seventy-five to ninety feet above the

base of the Black shale series. These greenish clay layers were believed by Linney to be the southern representatives of the Erie shale or Chagrin formation. As far as known, nothing has been done since Linney's day either to corroborate or disprove Linney's views. Nor is it known whether, in the light of recent observations, the large plates identified by Linney as *Dinichthys hertzeri* would be identified as this species at present.

In the Paleozoic Fishes of North America, published in 1889, Professor Newberry states that he suspects that the large fish plates, from Copperas creek, judging from drawings sent by Morris Fischer, represent gigantic *Placoderms* as yet undescribed.

In the Paleontology of New York, volume VIII, published in 1892, Hall and Clarke figure *Schizobolus truncatus*, Hall, from the Black shale of Madison county, and an unnamed species of *Lingula* from the Black shale near Vanceburg, Kentucky. The Black shale is identified as of Genesee age.

In the American Journal of Science, Volume 3, Fourth series, published in 1897, Professor H. S. Williams states that at Irvine the deposition of the Black shale probably continued beyond the period at which Carboniferous faunas appear in other regions. An equivalent statement is made in Contributions to Devonian Paleontology for 1903, by Williams and Kindle, published in 1905. However, Professor Williams fails to state what these Carboniferous species at Irvine are, and precisely where in the section they occur. They are said to come from somewhere near the top of the Black shale series.

In Volume 6 of the American Journal of Science, published in 1898, George H. Girty refers the Black shale to the Genesee. The species which usually has been identified as *Lingula spatulata*, Vanuxem, in Kentucky, he describes as *Lingula (Lingulipora) williamsana*, Girty, but it is noticed that Williams and Kindle do not use this name in their reports. The following species are identified by Girty at the Oil Springs, a mile northeast of Indian Fields, on Lulbegrud creek:

Lingula (Lingulipora) williamsana, Girty.
Leiorhynchus quadricostatum, Vanuxem.
Prioniodus arenatus, Hinde.
Sporangites huronensis, Dawson ?

From a locality two miles southwest of Jeffersonville, in Montgomery county, he lists:

Lingula (Lingulipora) williamsana, Girty.
Orbiculoidea ?
Leiorhynchus quadricostatum, Vanuxem.
Meristella, resembling *M. haskinsi,* Hall.
? *Plethospira socialis,* Girty.
Sporangites huronensis, Dawson ?

From the vicinity of Berea and Vanceburg *Lingula (Lingulipora) williamsana* is identified.

In the Twenty-fifth Annual Report of the Indiana Geological Survey, published in 1901, E. M. Kindle refers the southern part of the Black shale to the Genesee. The following species are identified from southern Indiana and the adjacent part of Kentucky:

Leiorhynchus quadricostatum, Vanuxem.
Leiorhynchus limitare, Vanuxem.
Chonetes lepidus, Hall.
Lingula spatulata, Vanuxem.
Barroisella subspatulata, Meek and Worthen.
Schizobolus concentricus, Vanuxem.
Orbiculoidea lodiensis, Vanuxem.
Styliola fissurella, Hall.

In the northern part of the State a Portage fauna is recognized in the Black shale.

In the Contributions to Devonian Paleontology for 1903, Williams and Kindle list the following species from the Black shale of Brooks, fifteen miles south of Louisville:

Chonetes scitulus, Hall.
Lingula spatulata, Vanuxem.
Leiorhynchus cf. quadricostatum, Vanuxem.
Pleurotomaria sp.

The writer has not attempted to collect fossils from the Black shale. Incidentally, several specimens of *Orbiculoidea* and *Lingula spatulata* were noticed along the road following the railroad at Alum Springs. Here these species occurred

about fifteen feet above the level of the railroad. *Lingula spatulata* occurs also at the tile works, at Searcy, near Moberly.

A study of the lists of fossils on the preceding pages indicates that the Devonian Black Shale of Kentucky unquestionably includes strata belonging to the Genesee formation. This is indicated especially by the presence of *Leiorhynchus quadricostatum, Schizobolus concentricus,* and *Lingula spatulata.* E. M. Kindle has shown that at Delphi, in northern Indiana, this Black shale includes also Portage or Nunda forms, especially *Spathiocaris emersoni.* Professor H. S. Williams has shown that in Virginia, at Hot Springs, the black shale sedimentation began as low as the Onondaga formation. Near Covington, in Virginia, he cites *Leiorhynchus limitare,* a Marcellus species, from the Black shale. In Ohio, Black shale sedimentation began with the base of the Delaware formation, where a series of thin fissile brownish shales, about six feet thick, makes its appearance. These brownish shales contain *Leiorhynchus limitare, Orbiculoidea lodiensis, Orbiculoidea minuta, Martinia maia, Tentaculites scalariformis,* and *Lingula manni.* They evidently belong to the Marcellus horizon. However, before conditions were favorable to the deposition of typical Devonian Black shales, changes in sedimentation occurred, and the limestones of the Delaware formation, of Hamilton age, and the greenish Olentangy shales, of unknown age, were deposited, so that in Ohio the first typical Black shale deposits appear to be of later than Hamilton age, corresponding thus to the Black shales of Indiana and Kentucky.

THE SILURIAN AND DEVONIAN OF SOUTHERN KENTUCKY, EAST OF THE CINCINNATI GEANTICLINE.

The Silurian is exposed also in southern Kentucky, along the Cumberland river, in Wayne county, at the mouths of Little Cub and Forbush creeks. At the mouth of Little Cub creek, the limestone at the base of the Silurian section is nineteen feet thick. The layer with *Whitfieldella subquadrata* and large crinoid beads occurs three and a half feet below the top of this limestone, and the underlying part is a typical development of the Brassfield bed. Overlying the limestone is greenish clayey shale, two and a half feet thick; clayey limestone, two feet thick; and an interval of nine feet, probably occupied entirely by green-

ish clayey shale. This part of the section corresponds to the attenuated lower part of the Crab Orchard division of the Silurian, as exposed west of Crab Orchard, toward Stanford.

A quarter of a mile above the mouth of Forbush creek, along a small stream entering from the north, the thickness of the limestone at the base of the Silurian section is fifteen and a half feet. The layer with large crinoid beads occurs twenty-one inches below the top. The underlying part corresponds to the Brassfield limestone. Nearer the mouth of the creek, back of the home of William Richardson, the layer with large crinoid beads contains also *Whitfieldella subquadrata.*

Silurian strata are exposed also in Pulaski county, about five miles directly west of Somerset, on both sides of Fishing creek. The exposures may be followed west of the creek, along a branch north of the home of V. L. Gossett. North of the bridge, the massive limestone at the base of the Silurian section is seven feet thick. Overlying this are distinctly bedded layers of limestone, forming a series ten feet thick. The top of this series of limestones is formed by a layer, one foot thick, containing *Whitfieldella subquadrata,* and the large crinoid beads, in addition to *Calymmene vogdesi, Dalmanella elegantula,* and *Cyathophyllum caliculum.* The underlying limestone, sixteen feet thick, unquestionably belongs to the Brassfield horizon. The thickness of the overlying clayey beds belonging to the lower part of the Crab Orchard division of the Silurian, could not be determined, although clayey beds of Silurian age are exposed for a distance of fully a mile up the creek. Farther north, the Silurian is overlaid by Devonian limestone.

The most southern outcrops of Devonian limestone occur along the branch separating the farms of Mrs. Al Loval and Sol Jones. Here the limestone is three and a half inches thick and is overlaid by coarse sandy material, half an inch thick. About a quarter of a mile northward, along the Sulphur Spring branch, the Devonian is two feet nine inches thick; it consists, in descending order, of coarse sandstone, six inches; fine-grained bluish limestone, one foot nine inches thick; and brecciated rock, four to six inches thick. A mile and a half northward, just above the home of John Freeman, the Devonian limestone is four feet thick; most of it is white and crinoidal, containing Cyathophylloid corals and large *Spirifers.* A short distance

northward, just above the home of Taylor Brock, the Devonian limestone is twelve feet thick; at the top the rock is cherty; just beneath, it contains Cyathophylloid corals; near the base the rock, five and a half feet thick, is massive and fine-grained. A short distance northward, just below the mouth of Coldwater branch, the Devonian limestone is seventeen feet thick, consisting, in descending order, of brecciated brownish rock, nine inches thick; white limestone, one foot; thin limestone layers, two and a half feet; massive limestone, seven feet eight inches; cherty limestone, two feet six inches; and fine-grained limestone, three feet. The Devonian limestone was traced three miles above the mouth of Coldwater branch; it is said, by people in the neighborhood, to occur in the vicinity of Adam's mill, two miles farther north.

A small number of fossils collected from this limestone was lost during transportation. These included several species of *Spirifer, Stropheodonta, Atrypa reticularis,* cyathophylloid corals and other fossils. Of these, only one specimen, closely related to *Amphigenia elongata,* is at hand. This was found in the neighborhood of the Sulphur Spring locality. The cast of the spondylium is shown distinctly. *Spirifer acuminatus* also occurs. These fossils indicate the presence here of strata equivalent to the Onondaga limestone of New York. The large number of corals and abundance of chert, at several localities, suggest the possibility of a southward extension of the Devonian limestone fauna seen in central Kentucky, and, farther north, in the Jeffersonville limestone, at Louisville, Kentucky.

THE SILURIAN-DEVONIAN UNCONFORMITY.

In east-central Kentucky, the Silurian formations thin out westward toward the Cincinnati geanticline and are overlaid unconformably by the Devonian formations. Along the crest of the geanticline, in Casey and Boyle counties, the Richmond division of the Cincinnatian series also is absent, and here the Devonian rests upon the upper part of the Maysville (Lorraine) division of the Cincinnatian.

North of Crab Orchard the Devonian rests upon at least seventy-five feet of clay belonging to that part of the Alger clay which overlies the massive limestone layer (marked C on

Plate A, page 64) a short distance above its base. If our interpretation of this part of the section be correct, the clay above this massive limestone layer corresponds to the Estill clay, and to the Waco formation, which here is nearly unfossiliferous and is represented only by clay. About two and a half miles west of Crab Orchard, along the pike to Stanford, the thickness of the clay above the massive limestone layer is sixty-six feet. About two and a half miles southwest of Crab Orchard, south of the county road, the thickness is at least fifty feet, but no accurate measurements are at hand. Three miles southwest of Crab Orchard, the thickness of this clay is thirty-five feet. About three quarters of a mile farther west, the thickness is twenty feet. A short distance farther west, at the home of William Pleasants, the thickness is eleven feet. Four and a quarter miles west of Crab Orchard station, the thickness of the clay is seven and a half feet. Half a mile farther west the Devonian limestone rests directly upon the massive limestone layer in the lower part of the Alger division of the Silurian. In this distance the Devonian limestone has been thinning irregularly from nineteen feet, west of Crab Orchard station, to about three or four feet at the exposure last mentioned. A short distance farther west, at the home of James Thomas Bailey, the red clay resulting from the decay of the Devonian limestone is only one foot thick, and it rests upon strata nearly ten feet below the level of the massive limestone layer, within two and a half feet of the Whitfieldella layer at the base of the Crab Orchard division of the Silurian, of which the Alger clays and limestones form the upper part.

Farther west, the Devonian limestone is absent, and here the Devonian Black shale rests directly upon the Brassfield limestone, the lowest Silurian formation in this part of the State. Of this Brassfield formation only the lower and middle part, eight feet five inches thick, remain. The upper part, including the layer with large crinoid beads, is absent. Farther west the Devonian limestone is present again, but rests upon Ordovician strata. It is possible that the absence of Devonian limestone south of Stanford, near Neal creek church, is due to the fact that, during the deposition of the Devonian limestone, the Brassfield limestone in this area projected so far above the level of the surrounding Silurian and Ordovician strata as to

be more strongly exposed to wave action or to tidal currents, and hence remained clear of Devonian deposits. Owing to its hardness, and the comparatively small quantity of interbedded clay, the Brassfield limestone would resist weathering and erosion better than the underlying part of the Ordovician and the overlying Silurian strata. Observations favoring this view are noted also at other localities in Kentucky.

As already stated, north of Crab Orchard the Devonian limestone rests on at least seventy-five feet of that part of the Alger clay which overlies the massive layer of limestone. Nine miles north of Crab Orchard, near the home of James M. Anderson, the thickness of this clay is only twenty-two feet. The Devonian limestone lies directly above. The Silurian strata probably once extended beneath the Devonian cover as far as Lancaster, but at present no exposures in that direction remain.

Along the pike between Crab Orchard and Stanford, exposures of the Devonian limestone are rather poor, but three miles east of Stanford, Devonian limestone waste occurs in considerable abundance within a short distance of the top of the Brassfield bed, suggesting the continuation of the features already described, from the area south of the Louisville & Nashville Railroad, as far north as Stanford, and probably as far north as Lancaster.

Northeast of Crab Orchard, toward Hammack, the Silurian-Devonian unconformity is also in evidence. The clay above the massive limestone layer in the Alger formation is at least seventy-five feet thick north of Crab Orchard. Along the headwaters of Harmon creek, it is thirty-seven feet thick. Near Hammack it varies between fifteen and twenty feet. The Devonian limestone lies directly above. It is probable that if more were known of the thickness of the Silurian formations where they now are under cover, in the northwestern part of Rockcastle county, it would be evident that the thinning of the Silurian formations here is toward the northwest rather than toward the northeast. Along Fall Lick creek, for instance, northeast of Crab Orchard, the thickness of the clay above the massive limestone layer is known to be much greater than at the head of Harmon creek.

Along the line between Garrard and Madison county, the evidence is less striking. Along Rocky branch, the base of the

Devonian limestone is thirty-four feet above the top of the Brassfield limestone, with its layer of large crinoid beads; the Devonian here rests upon a massive layer of limestone. About a mile northwestward the interval is only 22 feet, and a mile and a half northward it is thirty-five feet, no allowance being made for the dip of the rock.

Along the railroad, north of Berea, the Silurian-Devonian unconformity is well shown. Less than three miles north of Berea, the Devonian limestone appears to rest directly upon the massive limestone at the base of the Waco division of the Alger formation. The layer with large crinoid beads at the top of the Brassfield bed is found thirty-one feet below the Devonian. Half a mile south of Whites, the Devonian rests directly upon some of the layers of the Oldham limestone, containing *Stricklandinia norwoodi,* and the layer with large crinoid beads is found only twelve feet below the Devonian. At the same time, the Devonian limestone, which is thirteen and a half feet thick north of Berea, is reduced to three inches near Whites, being represented by the fish layer. Here again the Brassfield bed may have risen above the level of the upper Ordovician and the overlying Silurian strata during the deposition of the Devonian limestones in the neighboring parts of this section of Kentucky, producing features resembling those described from the vicinity of Neal's creek church, south of Stanford.

Evidences of the presence of the Silurian-Devonian unconformity appear also southeast of Bobtown. At Mat Moody's store, two miles and a quarter southeast of Bobtown, the Devonian limestone occurs about forty-eight feet above the base of the Brassfield bed. A mile farther northward, this interval is about thirty-six feet. Near the Mat Moody store the thickness of the Devonian limestone is at least three feet. A mile northward it is nine inches, and here the Devonian limestone is represented by the fish layer and rests upon clay.

In the greater part of the area between Whites and the exposures three miles east of Bobtown, the Devonian limestone does not exceed twelve inches in thickness and does not rest on the Brassfield limestone. In this area some of the minor limestone layers, such as the layer at the base of the Waco horizon, may have resisted erosion sufficiently to keep this part of

the field at a higher level during the deposition of the Devonian limestone.

Evidences of the Silurian-Devonian unconformity are seen along the railroad between Irvine and Brassfield. North of Irvine the Devonian limestone rests upon the Estill clay, sixty feet thick. East of Panola, about a quarter of a mile, the Estill clay is well exposed for a thickness of about forty-five feet, but the Devonian limestone is not seen at the point where this measurement was made. At Brassfield (Fig. 8), along the railroad cut, the Devonian limestone rests upon clay, fifteen feet thick. The horizon of the top of the Lulbegrud clay at Brassfield is fully seventy-two feet below the level of the top of the Estill clay at Irvine, and at least fifty-six feet below the top of the Estill clay at Panola. It is evident that the greatest unconformity is shown between Brassfield and Panola, and much less between Panola and Irvine. No explanation for this fact has been discovered.

Between Elliston, Waco, Cobb Ferry, College Hill, and the exposures three miles north of College Hill, the degree of unconformity is relatively very small, although considerable differences in the thicknesses of the Devonian limestone exposures are noticed.

Apparently there is a strong Silurian-Devonian unconformity in the area between Vienna and Merritts and Rightangle. South of Vienna the Devonian limestone rests upon some part of the Estill clay, and the massive limestone at the base of the Waco horizon is poorly exposed along the road north of Vienna. A mile north of Merritt, near the Old Simpson Brock place, the Devonian rests apparently, in case there is no fault, on the Oldham limestone. Northeast of Arlen, the Devonian, if not brought near the Brassfield bed by a fault, must be within a short distance of the top of the latter.

North of Vienna, along the road from Vienna to Indian Fields, the massive limestone layer at the base of the Waco horizon, and also at least the base of the Estill clay are exposed. Between Log Lick church and the home of J. T. Elkins, the base of the Devonian limestone practically rests on the massive limestone at the base of the Waco horizon. A quarter of a mile south of Indian Fields, the lower part of the Estill clay, about twelve feet thick, is exposed beneath the Devonian lime-

Fig. 8. Contact between Estill Clay and Devonian limestone at Brassfield, along the Louisville and Atlantic R. R.

stone. At the great clay pit along the railroad northwest of Indian Fields, this interval is seven feet. Along the railroad between Virden and Clay City (Fig. 9), the Devonian rests on the Waco bed or upon only a very small part of the Estill clay section. Between Tipton ferry and the Plum creek exposures, the Devonian rests upon the lower part of the Estill clay, only eight or nine feet thick. Comparing these sections with those found farther south, the degree of unconformity between the Silurian and Devonian is relatively slight.

There is evidently a remarkable thinning of the Estill clay between Irvine and Clay City. At Irvine, the Devonian limestone rests upon Estill clay at least sixty feet thick. Along the railroad west of Clay City this interval is reduced to less than ten feet, and at some localities can not exceed two or three feet.

There can be no doubt of a Silurian-Devonian unconformity between Indian Fields and Jeffersonville. At Indian Fields, the base of the Devonian is about fifty feet above the layer containing large crinoid beads, at the top of the Brassfield limestone. A mile southwest of Jeffersonville, this interval is seventeen feet. Half a mile northwest of Jeffersonville, the same interval is shown. At Indian Fields the Devonian limestone rests upon the lower part of the Estill clay, seven to twelve feet thick. Near Jeffersonville the Devonian rests upon strata probably equivalent to the Oldham limestone.

A greater degree of unconformity is shown between Spencer and Jeffersonville. East of Spencer, west of Slate creek bridge, the interval between the Devonian limestone and the layer with large crinoid beads at the top of the Brassfield limestone is sixty-two feet. East of the creek this interval is thirty-six feet. No account is taken in either case of the dip. Near Jeffersonville, this interval is seventeen feet. Two miles southwest of Preston the interval is seventy-five feet, and it is known to exceed sixty feet considerably directly south of Preston, about a mile. The records from the oil wells in the Ragland field indicate intervals of at least 160 feet between the Devonian limestone and the top of the Brassfield bed. At Owingsville the base of the Brassfield limestone is 100 feet below the center of the town; the waste of the Devonian limestone occurs practically in place in the northern part of the town, along the road

to Wyoming. The dip is eastward. The total thickness of the Silurian section is believed not to exceed 100 feet. There is evidence of a thinning of the Silurian section from the Ragland field toward Owingsville.

The well record from the Jack Barnett farm, in Menefee county, suggests the presence of at least 153 feet of Silurian clay. No exposures comparable with this are known in Montgomery county.

The thinning of the Silurian section, in east-central Kentucky, toward the west and northwest is evident, notwithstanding great irregularities in the rate and direction of this thinning. All the evidence so far collected in the field indicates that by far the greater part of the thinning of the Silurian section can not be due to the thinning of the individual members of the various Silurian formations, but must be due to the successive disappearance of the uppermost members of the various formations as these are traced westward or northwestward.

Two theories may be suggested to account for this. One of these assumes that the Silurian sections as seen at present are essentially the Silurian sections as originally deposited. The other assumes that formerly much greater thicknesses of Silurian rocks were present, especially toward, and possibly across, the crest of a great part, or of all of the Cincinnati geanticline, but that extensive erosion removed the upper part of these various Silurian sections, especially toward and along the crest of the geanticline, during the period preceding the deposition of the Devonian limestones of this area, which were deposited in Middle Devonian or Onondaga times.

Both theories assume the gradual elevation of Ordovician and Silurian strata in times preceding the deposition of the Middle Devonian. The first theory assumes that the elevation of the Cincinnati geanticline began in early Silurian, and possibly even in Ordovician times. The second assumes that the elevation resulting in the thinning of the Silurian sections began late in Silurian times, possibly even after the deposition of the latest Silurian strata still preserved in this part of the field.

According to the first theory, illustrated by Fig. 2, on Plate B, the elevation of the Cincinnati geanticline continued throughout the deposition of the Silurian. The Brassfield limestone,

Fig. 9. Devonian limestone, opposite the home of Green McDowell, west of Clay City, on the Lexington and Eastern Railroad, Powell County.

being deposited before the elevation of the geanticline had progressed far, extended farthest up the flanks of the geanticline. The Indian Fields formation, being deposited later, after the geanticline had attained a greater elevation, did not extend as

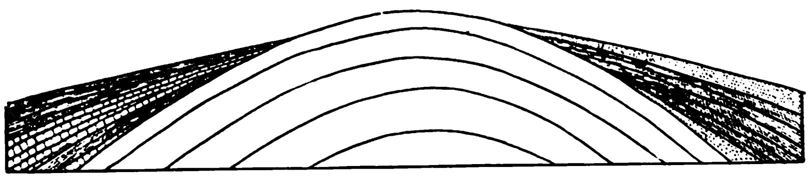


FIG 1. OVERLAPPING EDGES OF STRATA ON FLANKS OF SINKING ANTICLINE.

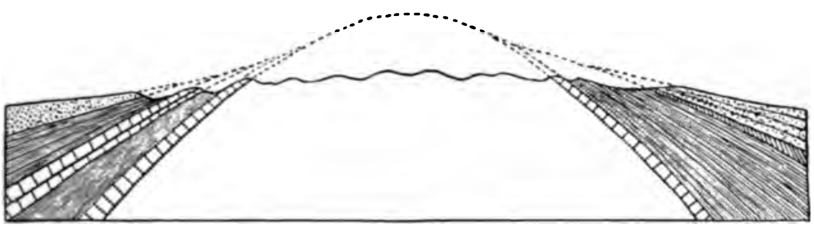


FIG 2. ATTENUATED EDGES OF STRATA ON FLANKS OF RISING ANTICLINE

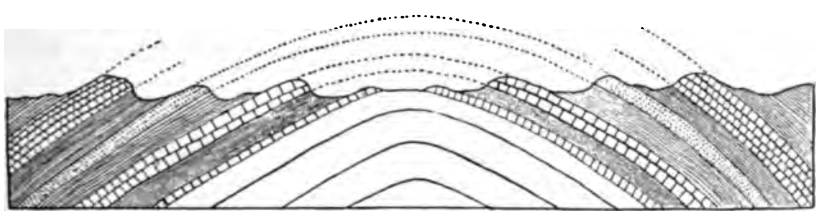


FIG 3. RISE OF ANTICLINE SUBSEQUENT TO DEPOSITION OF STRATA.

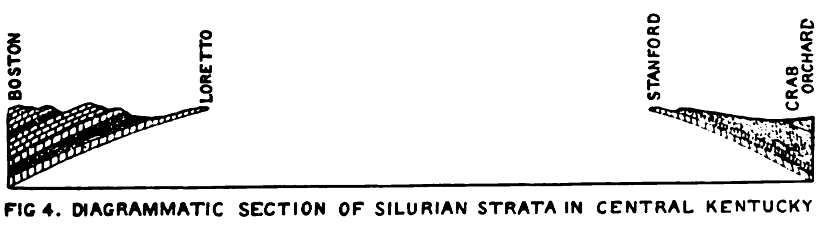


FIG 4. DIAGRAMMATIC SECTION OF SILURIAN STRATA IN CENTRAL KENTUCKY

Plate B. Illustrating various conditions resulting from the formation of geanticlines.

far toward the crest of the geanticline as the Brassfield limestone. By the time that the deposition of the Lulbegrud clay began, the elevation of the geanticline had increased so much that the Lulbegrud clay did not cover that part of the Indian Fields formation which lay nearest the crest. The elevation continued, so that the Waco deposits, where they can be recognized, do not extend as far up the flank of the geanticline as the Lulbegrud clay. Further elevation excluded the Estill clay from any but the more remote parts of the flanks of the geanticline. The thickest deposits of Estill clay are found farthest from the crest. This period of elevation was followed by a lowering of the area affected by the Cincinnati geanticline in east-central Kentucky. During this period of depression, the Devonian limestones extended across the edges of all the Silurian deposits as far as the Richmond and Maysville (Lorraine) areas along the crest of the geanticline. In support of this view of the continual elevation of the geanticline during Silurian times may be adduced the fact that no Silurian formation is known to extend farther up the flank of the geanticline than any of the preceding formations. There is no evidence of overlap preceding Devonian times, although there is some evidence of the thinning of certain Silurian formations toward the crest of the geanticline.

According to the second theory, illustrated by Fig. 3 on Plate B, the reason why there is no overlap of Silurian formation on approaching the crest of the Cincinnati geanticline is because there was no elevation of the Cincinnati geanticline of any considerable proportions either in existence, or in progress during Silurian times. Hence, Silurian strata were deposited in succession over a wide area covering the region now affected by the Cincinnati geanticline. The absence, at present, of Silurian strata over the more elevated parts of the Cincinnati geanticline is to be accounted for not by assuming that these strata never had been deposited where now they are absent, but by assuming that Silurian strata once were present, but were removed in later times, after the elevation of the Cincinnati geanticline, by weathering and erosion. The elevation of the geanticline in late Silurian and early Devonian times is assumed to have raised these former Silurian deposits which were along the crest of the geanticline into regions where waves

and currents were most effective, and possibly even where atmospheric agencies would assist in their removal. The result of erosion and weathering is assumed to have reduced a great part of the more elevated regions of the Cincinnati geanticline to the condition of comparatively flat country, but little elevated above the sea. Such a condition usually is spoken of as a base-level, and the topography produced by the same as a peneplain. The result of this removal of strata from the crest of the Cincinnati geanticline in late Silurian and early Devonian times was the exposure of only the older layers along the crest of the geanticline, and the outcropping of successively younger layers on passing from the crest of the geanticline outward toward its flanks. Subsequent erosion, not failure of deposition, is assumed to account for the absence of Silurian strata along the crest of the Cincinnati geanticline. Reduction of the upper part of the geanticline to a peneplain, and not progressive elevation of the geanticline during the period of deposition of Silurian strata, is assumed to account for the apparently more restricted areas of deposition in the case of each of the successively later Silurian formations. The depression of this peneplain during Middle Devonian times permitted the deposition of the Devonian limestones (Onondaga) of Kentucky.

According to the first theory, those parts of the Silurian formations of east-central Kentucky which lie farthest west, nearest the crest of the Cincinnati geanticline, are, therefore, nearest the shoreline, as it existed during the deposition of this particular formation. According to the second theory, there was no shore line along the flanks of the Cincinnati geanticline, since this geanticline is assumed not to have been sufficiently developed as yet to give rise to dry land and a shore line. According to the first theory, evidences of proximity to the shore should be sought along lines of outcrops nearest the crest, and these evidences should become less pronounced, and should finally disappear on going from the crest toward the flanks of the geanticline. According to the second theory such evidence should not be at hand. According to the first theory, the Silurian faunas on the two sides of the Cincinnati geanticline might have developed distinct features, notwithstanding the connection of these areas farther north, in Ohio and Indiana. According to the second theory, the faunas on the two sides of

the Cincinnati geanticline should not differ more than faunas equally distant in areas more directly connected.

Both theories assume conditions of weathering and erosion in times preceding the deposition of the Devonian limestones. According to the first theory, this erosion began in early Silurian times, or even during the Ordovician. The second theory assumes that the erosion began in late Silurian times.

According to the first theory, the lithological character of the deposits on the opposite sides of the geanticline might be expected to show greater differences (See figures 1 and 2, on plate B), perhaps, than if the conditions predicated by the second theory prevailed.

Very little evidence in favor of either theory has been discovered so far.

Pebbles and wave-marks have been discovered in some Silurian strata, especially in the Brassfield limestone and in immediately overlying strata, but it has not been shown that these occur in the beds nearest the crest of the geanticline and are absent at greater distances. Crossbedded layers are known, especially in the Brassfield limestone, but it has not been shown that these are best developed nearest the crest of the geanticline. No distribution of species of fossils has been discovered suggesting the presence of shore conditions in those parts of the Silurian deposits of east-central Kentucky which are exposed farthest west. At no point is any Silurian formation known to be resting upon the eroded surface of earlier strata, filling up an earlier water channel, butting up against the side of a cliff, or presenting any other evidence of distinct unconformity. In general, it may be said that evidences favoring shore condition, so far collected, do not serve to determine the location or direction these shores, nor are these evidences of such a character as to demand the presence of any elevation of land following the same general direction as that now taken by the geanticline.

The lithological characteristics of the strata east and west of the geanticline present not only certain differences, but also certain strikingly similar features. If the Alger formation of east-central Kentucky corresponds to the main body of Osgood clay in the west-central part of the State, and if the Brassfield bed corresponds to the so-called Clinton limestone of that part

of the State, it is evident that the Plum creek clay and the Oldham limestone of east-central Kentucky can be represented on the western side of the geanticline only by the layers of limestone at the base of the Osgood clays. The latter rarely present a thickness of more than two feet. At the most eastern exposure known, about six miles east of Bardstown, along the railroad, a mile and a half east of Woodlawn station, formerly known as Gasburg, thin limestones interbedded with clay, forming a section four feet thick, occur at the base of the Osgood clay section, overlying the so-called Clinton. This may represent the western extension of the Indian Fields formation, this being the formation which includes the Plum creek clay and Oldham limestone, as already mentioned.

Both the Alger clay and the Crab Orchard clay present their thickest sections farther south, in east-central and west-central Kentucky. Northward, in Ohio and Indiana, these clays are represented by thinner sections, and, before reaching Dayton, Ohio, and Richmond, Indiana, become not only much thinner, but also are largely replaced by argillaceous limestones. These facts favor the view that the Silurian areas east and west of the geanticline were connected at least during the deposition of these clays, although this connection may have been only across central Kentucky, through Boyle and Marion counties. The evidence is very inconclusive.

The fossils found in the Brassfield limestone, east of the geanticline, and those found in the so-called Clinton limestone, west of the geanticline, are merely a meagre representation of the so-called Clinton fauna of Ohio and Indiana, and show no differences suggesting their development in different basins.

The abundant Whitfieldellas in the sandy limestone layer, immediately above the top of the Brassfield limestone of eastern Kentucky are unknown west of the Cincinnati geanticline, in Kentucky, although related forms are found in the Osgood bed in Ripley county, Indiana.

The Stricklandinia found near the top of the Oldham limestone is not known west of the geanticline, but specimens of Stricklandinia of a somewhat smaller species are found at the top of the limestones beneath the Osgood clay about six and a half miles southwest of Bardstown, and occur also at several localities in western Tennessee. Of the other fossils found

in the Oldham limestone comparatively little is known, at present, but it may prove that this fauna will show closer relationship with the Brassfield fauna than with the Waco fauna, and that the Oldham fauna will find representatives in the upper part of the so-called Clinton in western Kentucky, which is represented by the white limestones in Nelson and Marion counties, especially in the neighborhool of Bardstown. This white limestone differs considerably in appearance from the salmon brown limestone characteristic of the Clinton in northern Kentucky, and the adjacent parts of Indiana, and may represent a somewhat higher horizon.

The Waco fauna is different from anything known in the Osgood formation, either in western Kentucky or Indiana. It may have formed in a different basin from the latter. The Cincinnati geanticline may already have developed sufficiently during the deposition of the Waco bed to make it possible for a fauna to develop in eastern Kentucky quite distinct from the faunas of western Kentucky, but the evidence does not point to this conclusion necessarily. The Brassfield deposits of eastern Kentucky and Ohio are represented only in part farther west, in southeastern Indiana and the adjacent parts of western Kentucky. It may be that the Osgood formation, west of the Cincinnati geanticline, in a similar manner represents only a part of the Crab Orchard division of the Silurian farther east. It may be attenuation of formations toward the west, in times preceding the formation of the geanticline, attended with omission of part of the series farther westward, rather than the development of distinct faunas in separate basins, on opposite sides of the geanticline, which will prove the explanation of the few facts known so far.

In general, it may be stated that the study of faunas along the Cincinnati geanticline has not progressed sufficiently as yet to determine the things we most would like to know. Of course, speculation on this subject is to be expected, but it is worth while to remember that the number of facts upon which these speculations must be based is still very small.

While there is no doubt of the existence of the Cincinnati geanticline in pre-Onondaga times, preceding the deposition of the Devonian limestones of this area, the Silurian, Cincinnatian, or even earlier origin of this geanticline requires further investi-

gation. Such an early origin may be probable, but probability must not be confounded with proof and fact.

The Devonian Limestone-Black Shale Unconformity.

In the Report of Progress of the Ohio Geological Survey for 1870, Professor Orton publishes the following very interesting facts:

At Delaware and northward, the Ohio Black shale rests upon a thin belt of shale, at that time identified as the Hamilton, but now known as the Olentangy shale. In Franklin county, of which Columbus is the county seat, the Black shale rests upon the Corniferous limestone, now known as the Delaware and Columbus limestones. In Ross county, in which Greenfield is located, the Black shale rests upon the Greenfield limestone, referred at present to the Monroe formation. In Highland county, the Black shale rests upon the Niagara formation, the highest member of which in this county is called the Hillsboro sandstone. There is a very evident unconformity between the base of the Devonian Black shale and the underlying Devonian and Silurian formations. The absence of the Monroe formation west of the Cincinnati geanticline requires explanation.

In a paper on the Devonian and Lower Carboniferous faunas of southern Indiana and central Kentucky, E. M. Kindle shows a striking unconformity between the base of the Black shale and the Devonian (Jeffersonville) limestone at Brooks run, in Bullitt county, Kentucky, fifteen miles south of Louisville. Erosion preceding the deposition of the Black shale had produced gullies, in the top of the limestone, fully ten to twelve feet deep. Another very marked unconformity was discovered a quarter of a mile south of Huber, in the same county. Here the Black shale rests on the Sellersburg division of the Devonian limestone. It is probable that further observations will result in the discovery of similar evidences of unconformity elsewhere in the field.

In this connection attention should be called to the fact that, in several areas in Kentucky, the Devonian limestone is entirely absent. This is the case, for instance, in part of the area between Bardstown and New Haven, between New Haven and Raywick, between Raywick and Loretto, south of Stanford east of Neals creek church, for at least five miles north and

northeast of Liberty, everywhere along the Cumberland river west of Fishing creek. These localities are all along the more elevated parts of the Cincinnati geanticline in that part of its extent where the Black shale is still preserved, and the absence of the Devonian limestone here is undoubtedly connected with the elevation of the geanticline.

A similar absence of Devonian limestones is noted in the area between the southeastern corner of Fleming county, in Kentucky, and Pickaway county, in Ohio. This has led to the belief that, in times preceding the deposition of the Black shale, a subsidiary anticline passed northeastward across this part of the country, the crest crossing the Ohio river some where in the neighborhood of Vanceburg.

Where the Devonian limestone is reduced to a very thin layer, often less than one foot in thickness, between Whites and the exposures three miles east of Bobtown, it is noticed that the layer containing fish teeth and plates still remains. Similar features are noticed elsewhere, for instance a quarter of a mile south of Indian Fields, where only a thin exposure of Devonian limestone occurs. This fact has suggested that in some areas it may be the upper, rather than the lower part of the Devonian limestone section which may be absent, again suggesting an unconformity. The fact that rocks equivalent to the Delaware limestone and to the Olentangy shale appear to be absent would lead to similar conclusions.

The presence of a thin strip of Black shale below the brown rock regarded as equivalent to the Duffin layer, which has been noted at several localities, suggests that in some areas the deposition of the Black shale may have begun earlier than in others.

The Lexington Peneplain.

In discussing the topography of that part of Kentucky which lies within twenty miles of Richmond, Marius R. Campbell makes the following statements:

The most striking topographic feature of this area is the great plain of central Kentucky, which shows to excellent advantage at Winchester, Richmond, and Berea, and which is named the Lexington peneplain from the city of Lexington. When viewed from a single locality the apparent parallelism between the surface of this plain and the bedding of the rocks

suggests that it was formed by the erosion of soft beds down to the surface of a more resistant stratum, but when a large area is examined it is found that this plain truncates the Cincinnati geanticline, causing different beds of rock to form the surface in different portions of the plain. In view of this fact it is not possible to ascribe the formation of this topographic feature to the influence of hard beds of rock, or to the geologic structure. There are two methods by which this plain may have been produced: either by the shore action of the waves of a large body of water, or by sub-aerial erosion of the land to base-level. If this feature was produced by waves, central Kentucky must have been beneath the water of the ocean at some time since the Paleozoic era, later than the time of deposition of Carboniferous or Pennsylvanian strata. If the sea covered this territory, there must have been sediments deposited on its surface; but no such material has ever been discovered: therefore this cause seems not to have operated to produce the plain in question. Subaerial erosion on the land surface which is free from movement will produce such a feature if time enough is allowed for the approximate reduction of the surface to base level. The surface resulting from such conditions will be almost a plain—a peneplain. This hypothesis is in accord with the facts in central Kentucky, so far as known, and consequently this feature will be regarded as of subaerial origin, and it will be referred to as the Lexington peneplain.

The hills which rise above the Lexington peneplain have a fairly constant altitude of about 1,500 feet above sea level. They have generally round or sharp tops, which give no suggestion of a higher plain; but the regularity of altitude, despite the variation of the underlying rocks, is strong evidence of the former existence of a peneplain at this level, which has been so completely dissected by later erosion that no trace of its surface remains to mark its exact position.

The valleys which are cut below the surface of the Lexington peneplain are complex in character and show that they are the result of two episodes of erosion. When viewed upon the ground it is apparent that there is a long, gentle slope from the surface of the Lexington peneplain leading down to the brink of steep walls which bound the inner valley of the river. The gentle slopes constitute the sides of an older valley, which

was broad. The narrow modern gorge of the Kentucky river has been cut within it.

Upon the floor of the older valley occur deposits of sand and clay which were laid down by the river when it occupied this valley, before the inner gorge was cut out. In order that such widespread deposition should have taken place, the streams must have had moderate fall and have been unable to carry farther the load of sand and mud which they carried with ease in the narrow, upper valley in the Coal Measure plateau. The sediments were laid down in a sort of delta deposit across the entire width of the old valley; they are now found only on the tops of the river hills which mark the surface of the intermediate valley.

No direct evidence has been found in the area under investigation, within twenty miles of Richmond, of the dates of the peneplains or of their allied surface features. The Lexington peneplain and the one 500 feet above it are continuous with similar features throughout the southern portion of the Ohio Basin and the Gulf slope, and it is to these distant portions of the province that we must look for evidence regarding their dates. The higher peneplain can be traced continuously southward to the margin of the Cretaceous sediments of the Gulf coast; it is also a part of the great peneplain which shows over most of the Appalachian province, and which is generally referred to the Cretaceous period. It is obviously very old, and since all of the evidence available agrees with the foregoing statement, it will be accepted as provisionally correct.

The Lexington peneplain is commonly regarded as of post-Cretaceous age, but the period has not yet been satisfactorily determined. The only definite theory yet advanced regarding its age makes its age contemporaneous with the Eocene limestone of the Gulf slope. This has been advocated only as a working hypothesis, but so far as known it is in harmony with the facts found in this region, and will be accepted provisionally. On the assumption that the Lexington plain is of Eocene age, the intermediate valley and the deposits connected with it would presumably be referred to the next succeeding period, the Neocene, and the inner gorge to the remaining portion of the Neocene and the Pleistocene. This determination must be accepted as merely provisional, and subject to change when more direct evidence becomes available.

—Lexin
pene

Fig. 10. Knobs and hills rising above the Lexington peneplain. View looking from the road east of Brassfield southward across the peneplain. Estill and Madison Counties.

The preceding observations by M. R. Campbell, quoted with few alterations, are so interesting that they have been given in full. The Lexington peneplain covers the great central limestone area of Kentucky. The Black shale and Waverly knobs surround the Lexington peneplain, and form the advance guard of the remnants of the earlier, Cretaceous peneplain. The difference in elevation often is striking. The sharp contrast between level of the strata forming the surface of the Lexington peneplain and the tops of the knobs beyond is well shown by a view from the road northeast of Kiddville, southeastward; also, from the great clay pit half a mile west of Indian Fields, northeastward, and toward the southeast; from the road several miles north of College hill, eastward; from the road a short distance east of Brassfield, southward (Fig. 10).

THE IRVINE FORMATION.

Marius R. Campbell gives the following description of the Irvine formation:*

"The Irvine formation consists of unconsolidated sand, gravel, and clay, which originally covered the intermediate valley of the Kentucky river near the eastern edge of the Richmond quadrangle, the area within twenty miles of Richmond, but which are now found capping the river hills—the few remnants of what was once an extensive and continuous surface. It is named from the town of Irvine, which is located on the Kentucky river, twenty miles southeast of Richmond. No fossils have been found in these sands by which to ascertain their position in the geologic time scale, so that we are forced to fix their age by their relation to the topography of the region. Unfortunately, the dates of the principal topographic features have not been accurately determined, and that of the Irvine formation can be stated only provisionally, but its close connection with the Lexington peneplain certainly indicates that it is much older than the Pleistocene period. Since the sand occurs on the floor of the intermediate valley of the Kentucky river, and is dissected by the erosion which produced the gorge of that stream, it must have been deposited in the period that intervened between the cutting of the intermediate valley and the cutting of the gorge. The geologic period in which the intermediate valley was eroded has not been determined with

*Richmond, Ky., Folio, U. S. Geological Survey, 1898.

certainty, but since it is cut only a slight distance below the surface of the Lexington peneplain, and to only a moderate breadth, it must have been formed soon after the peneplain was raised above sea-level. The age of this peneplain has been provisionally accepted as Eocene, and that of the intermediate valley as Neocene; hence the deposits lying upon the floor of the intermediate valley must have been laid down after the valley was cut, or presumably in the closing stages of the Neocene period."

On the geological map which accompanies the Richmond folio, published in 1898, Mr. Campbell indicates certain areas between Brassfield, Irvine, and the Kentucky river as containing strata of Irvine age. A study of the areas delineated as underlaid by the Irvine formation between Portwood, or Bybeetown, and Cobb ferry, northeast of Waco, and near College Hill, indicates that the Irvine formation here is the source of the clays from which the pottery-ware, which is manufactured at Waco and Bybeetown, is constructed. Extensive private surveys by the Searcy Roof-tiling Manufacturing Company have demonstrated the presence of these clays over wide areas in the territory indicated. Extensive sandy beds, as well as more limited pure, plastic clays, occur. These deposits rest on the eroded surface of the Devonian Black shale. The deposits at Irvine also rest upon these shales.

Exposures of the Irvine formation are much more extensive than indicated on this map. They occur at numerous points above the 800-foot contour line in the area between Waco, Irvine, Clay City, and Indian Fields, always resting on the Devonian Black shale. An excellent exposure forms the top of the ridge east of Long branch, six miles south of Indian Fields. At the great clay pit along the railroad west of Indian Fields, the thickness of Irvine clay varies from two to five feet. It is very sandy and contains pebbles. Along the road from Indian Fields to the Oil Spring, and, again, south of the home of John Goff, Irvine deposits rest upon the phosphatic nodule layer at the base of the Waverly series. Along the road southwest of Clay City, from Tipton ferry to Plum creek, the Irvine formation rests on Black shale, is sandy, and contains pebbles fully three quarters of an inch in length.

East of Clay City the Irvine formation may be traced up the valley of the Red river to Rosslyn, at the mouth of Cat creek.

Here it rests upon Waverly clay, of which a thickness of ten feet is exposed; the Waverly clay contains thin interbedded layers of ferruginous indurated rock. Above this level is a gravel bed containing both angular and rounded pebbles, consisting of free-stone, quartz, and chert derived from the upper limestones of the Mississippian deposits of this part of Kentucky. The thickness of this gravel layer is two feet nine inches. This is overlaid by sandy clay, six feet thick, followed by a considerable deposit of whitish clay, about thirty feet thick.

From Irvine and Brassfield the Irvine formation may be traced southwestward, everywhere resting on the eroded Black shale. White Irvine clay, with ferruginous sandy material in it, occurs at the Bear Wallow, three miles east of Bobtown; also, southwest of Bobtown, northeast of the New Liberty church. Similar exposures occur at numerous exposures between Cartersville and Wallaceton, and also westward, toward Crab Orchard. Southwest of Crab Orchard, the Irvine formation is exposed along the county road west of the main branch of Cedar creek, resting upon Silurian deposits.

The only deposits which have proved to be of economic interest, so far at least, are those near Waco. Elsewhere the sandy element in these clays has proved an injurious feature. This does not mean, however, that it is useless to look for other deposits of Irvine clay which might be useful for pottery. Owing to the small amount of overlying material to be removed, even comparatively thin layers of plastic white clays would have considerable value provided they were of the desired chemical composition.

Derivation of Sediments from the Waste of the Cincinnati Geanticline.

In the American Journal of Science for 1897, Professor H. S. Williams states his belief that a large share of the Black shale material was derived from the waste of the Cincinnati geanticline, that the Black shale mud was distributed over the area where Black shale deposits now are known by a large current similar to the Florida current, which is a branch of the Gulf Stream. In the area between the Cincinnati geanticline and the most eastern exposures of the Black shale in Virginia the Black shale muds of the Black shale series are believed to

have come from the Cincinnatian arch, while the arenaceous sediments belonging to this series are believed to have resulted from the disintegration of Archaean rocks farther eastward, in the territory to which Professor Williams applies the term Appalachia. These arenaceous sediments increase in quantity and are found lower in the Black shale section on approaching the land edge of the Appalachian territory. Toward the Cincinnati geanticline, however, the deposition of black shale muds continued for a much longer period.

In a paper on the Silurian and Devonian limestones of Tennessee and Kentucky, published in 1901, the writer advocated the idea that the plastic material of this clay might have had an origin similar to those deposits of loess which appear to have resulted from the dissemination of wind-blown dust which found its final lodgment in moist areas, swampy lands, or shallow seas devoid of currents strong enough to sweep these light sediments away. As matters stand at present, this theory is founded rather upon imagination than observation.

It is evident that not only the source of the clastic material of the Devonian Black shales, but also the source of the extensive and thick deposits of the fine-grained Linietta clay at the base of the Waverly series requires explanation. Why do the Black shales contain so much carbonaceous material and the Linietta or Bedford shales, of east-central Kentucky, so little? What caused the abrupt change from carbonaceous to non-carbonaceous deposits? If the Black shale deposits were formed by muds derived from the disintegration of rocks along the Cincinnati geanticline, was the source of the Linietta clays not the same?

In the Richmond folio, published in 1898, Marius R. Campbell refers to the Irvine clays used in the manufacture of pottery at Waco as residual clay of the shale member of the Panola formation. The Panola formation includes the Silurian deposits of east-central Kentucky, and also the Devonian limestones of this area. The shale member of this formation includes the Alger formation, the upper part of the Crab Orchard division of the Silurian. These clays were once exposed much farther east up the flanks of the geanticline than at present, so that the statements by Mr. Campbell may be interpreted as equivalent to saying that the Irvine clays at Waco were derived from the direction of the Cincinnati geanticline.

DETAILED ACCOUNT OF SECTIONS OF SILURIAN AND DEVONIAN ROCKS OF EAST-CENTRAL KENTUCKY.

GENERAL INDEX.

In the following detailed account of the various sections of Silurian and Devonian limestones studied in east-central Kentucky the aim has been to enable those interested to learn precisely what deposits may be found at each locality named. The sections described have been selected in such a manner that practically the entire territory between Stanford and Owingsville where Silurian and Devonian deposits are known to occur, has been covered, and any one interested in any special district can find described some section sufficiently near this district to enable this investigator to recognize also the strata which are present in the area in which his special interest centers.

West of Berea the subdivisions of the Crab Orchard division of the Silurian have not been determined definitely. The correlations indicated in the descriptions and on the plates of sections are merely provisional.

The number given at the beginning of each section described is the number by means of which the locality is designated on the accompanying maps and sections. The letters preceding the hyphen (-) indicate the atlas sheet or quadrangle of the Geologic Atlas of the United States on which the number is to be found, and the letters following the hyphen (-) indicate the section of this quadrangle on which the number is located, while the page on which the map is found is given in the table below, as follows:

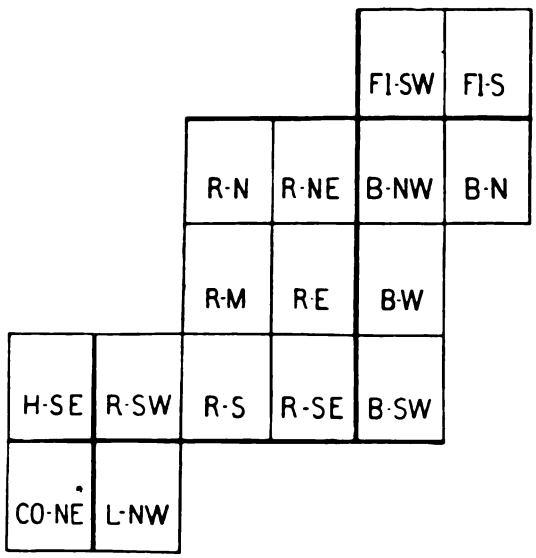


Diagram indicating relative position of road maps accompanying this bulletin.

	Quadrangle.	Section.	Map on Page
CO-NE	Crab Orchard	Northeast	140
L-NW	London	Northwest	140
H-S	Harrodsburg	South	140
H-SE	Harrodsburg	Southeast	140
R-SW	Richmond	Southwest	155
R-S	Richmond	South	167
R-SE	Richmond	Southeast	173
R-E	Richmond	East	173
R-NE	Richmond	Northeast	185
B-W	Beattyville	West	173
B-NW	Beattyville	Northwest	193
Fl-SW	Flemingsburg	Southwest	202

See Index of Maps and Localities at the end of this Bulletin

A. Sections West of Stanford.

(Map 1, page 140.)

North of Junction City, three quarters of a mile north of the railroad crossing, at Duffin cut.

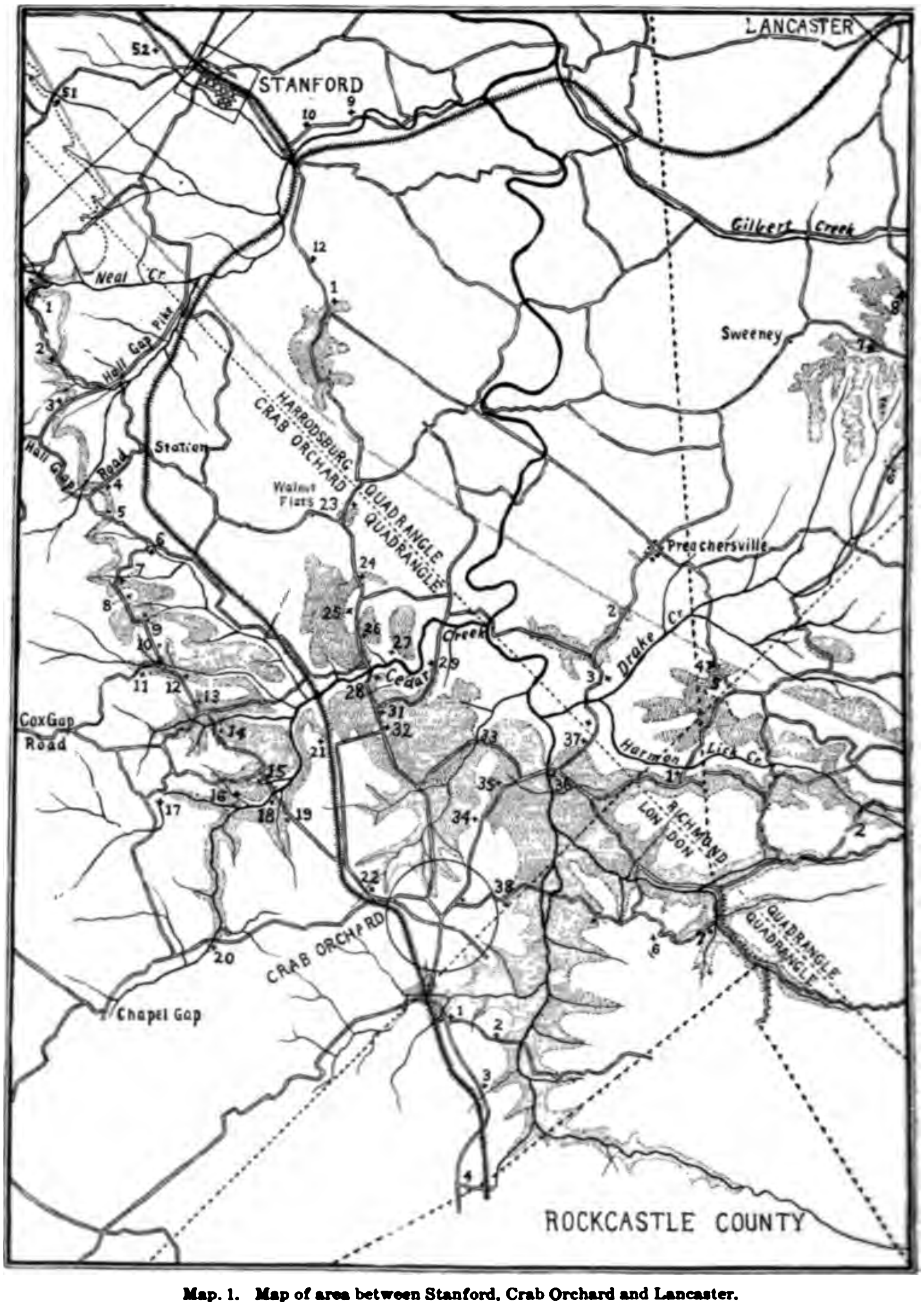
Black shale.		
Rock having a brecciated appearance, weathering brown, containing a few crinoid stems and corals, the weathered surface occasionally showing numerous small quartz concretions. Sometimes not having the brecciated appearance, and then well-bedded. It contains fucoidal markings. This layer may conveniently be called the Duffin layer. It appears to be widely distributed	6 ft.	
Bluish white siliceous limestone, full of chert layers and concretions, with Devonian corals	4 ft.	8 in.
Dense bluish white limestone		6 in.
Dense bluish white limestone, with chert, and with *Cystiphyllum*	2 ft.	4 in.
Thin shaly limestone, badly weathered, with fennestelloid bryozoans and other fossils		4 in.
White dense limestone, with abundant chert concretions of small size, also with large crinoid stems at top	2 ft.	
Dense light gray limestone, with *Reticularia fimbriata*, and large fucoidal markings, *Taonurus caudagalli*, near the base, and with fish teeth just above the base	2 ft.	6 in.
Top of Ordovician, Richmond division.		
Clay rock, cracking irregularly	7 ft.	
Fault at north end of cut.		
Rock, with *Platystrophia lynx*, *Lophospira bowdeni*, *Lophospira tropidophora*, belonging to the Maysville division.		

52 H-S.—At the Buffalo spring, about a quarter of a mile west of Stanford, on the pike to Hustonville.

Black shale.	
Brecciated or Duffin layer. Total thickness of Devonian rock	11 ft.
Devonian faulted against the Ordovician.	

Three quarters of a mile southwest of the Buffalo spring, west of Stanford, and then about half a mile northwest of the pike, along another road.

Here six feet of Devonian limestone is exposed beneath the Black shale. The total thickness is unknown.



Map. 1. Map of area between Stanford, Crab Orchard and Lancaster.

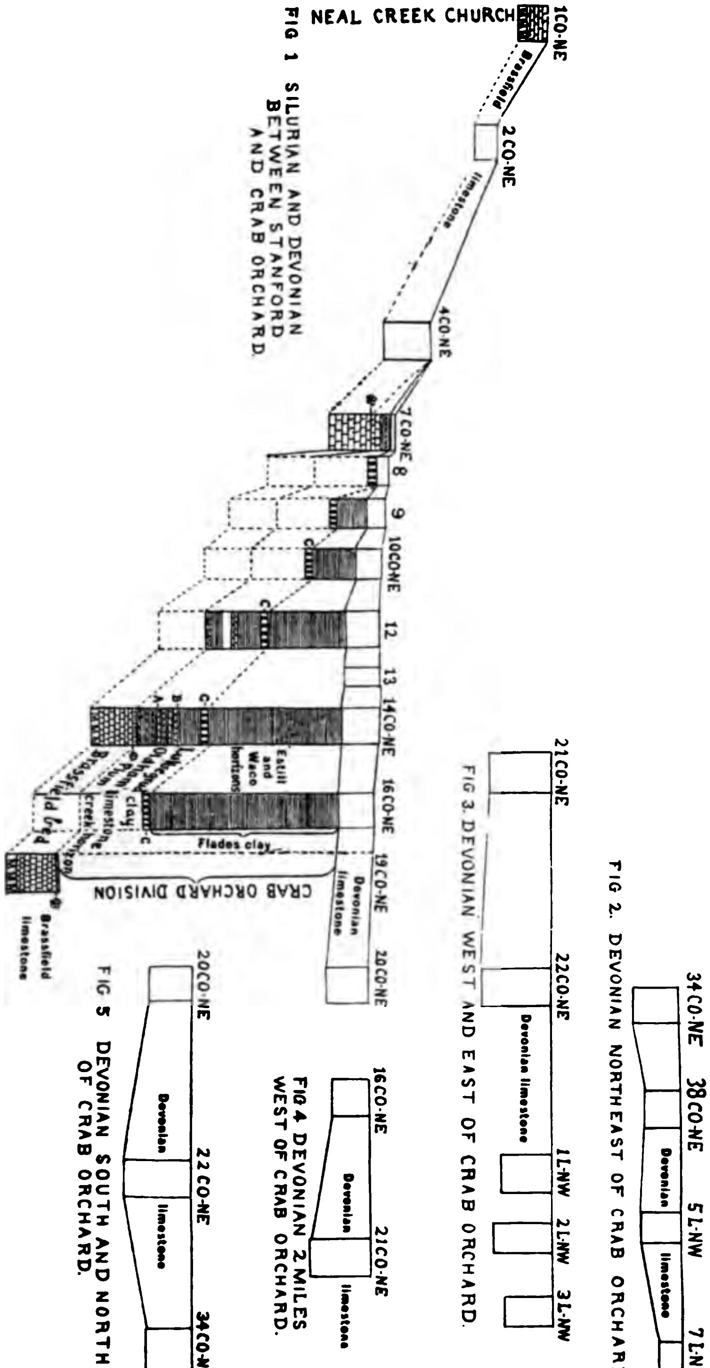


Plate C. Sections of Silurian and Devonian Strata between Stanford and Crab Orchard.

Much Devonian chert is found half a mile south of the pike, along a road turning off a short distance westward.

B.—Sections Between Crab Orchard and Stanford, South of the Louisville & Nashville Railroad.

(Figure 1, plate C, page 141.)

20 CO-NE.—Southwest of Crab Orchard, about two miles from the railroad station, east of the road leading to Chapel Hill, east of the east fork of Cedar creek, near the bridge.

The thickness of the Devonian limestone is eleven feet. The contact with the Black shale is exposed.

17 CO-NE.—Southwest of Crab Orchard, about three miles in a direct line from the railroad station; reached by following the Chapel Hill pike almost three miles, and then turning off westward along a road which crosses the main fork of Cedar creek about a mile and a half from the pike.

The Black shale is exposed down the creek for a considerable distance. In one of the side valleys northeastward, a fine spring issues from beneath a massive exposure of Devonian limestone, nine feet thick. The Crab Orchard clay shale (Alger clay), along the upper part of the main fork of Cedar creek (16 CO-NE) is at least fifty feet thick. The total thickness is not exposed at any point visited so far.

19 CO-NE.—West of Crab Orchard, about a mile and a half west of the railroad station, along the county road a short distance west of the home of Cyrene G. Ware. This may be at the same locality as that described next.

Here the total thickness of the Brassfield bed, to the top of the layer containing numerous large crinoid beads, is thirteen and a half feet. The lower part of the section, two and a half feet thick, consists of massive limestone, while the overlying part consists of limestone layers of moderate thickness.

18 CO-NE.—West of Crab Orchard, almost two miles west of the railroad station, east of the crossing of the county road over a small branch of Cedar creek.

The contact between the Silurian and Ordovician is exposed. Of the Silurian, the lower part, twenty-three to twenty-five feet thick, is seen; this includes the more massive Brassfield bed at the base, and the more clayey beds with more or

less intercalated limestone (Indian Fields formation) immediately above. The Silurian limestones have weathered to a rusty brown. In the upper part of the Brassfield bed, the following fossils were found: *Orthis flabellites, Platystrophia daytonensis, Leptaena rhomboidalis, Cyathophyllum daytonensis,* and *Cyathophyllum calyculum.*

15 CO-NE.—West of Cedar creek, along the county road, the base of the Silurian section is formed by the more massive limestone, eight and a half feet thick, belonging to the Brassfield bed. This is overlaid by softer rock, about three feet thick, followed by more solid limestone, probably belonging to the horizon which elsewhere contains the large crinoid beads. Ten feet above this level, and for some distance farther west also at higher levels, there is a whitish clay occupying the horizon of the Crab Orchard clay shale, but resembling the clays of the Irvine formation.

14 CO-NE.—West of Crab Orchard, about three miles in a direct line from the railroad station, along the county road east of a branch of Cedar creek, at the home of Abel Bryant.

The following section is exposed, described in descending order:

	Thickness.	Total from base of section.
Red soil, containing Devonian brachiopods...........		
Crab Orchard clay shale (Estill and Waco horizons)....	35 ft.	64 ft. 2 in.
Massive limestone layer..............................	2 ft.	29 ft. 2 in.
Clay (Lulbegrud clay)................................	6 ft.	27 ft. 2 in.
Chiefly limestone, with some interbedded clay (top of Oldham horizon)...................................	2 ft.	21 ft. 2 in.
Poorly exposed.......................................	1 ft. 6 in.	19 ft. 2 in.
Solid limestone layer................................	8 in.	17 ft. 8 in.
Poorly exposed (Plum creek clay).....................	5 ft.	17 ft.
Limestone, large crinoid beads at base...............	1 ft.	12 ft.
More massive limestone, belonging to the Brassfield bed	11 ft.	11 ft.
Top of Ordovician.		

The following is a more detailed description of part of this section, also in descending order:

	Thickness.	Total from base of section.
Reddish brown limestone	1 ft. 6 in.	30 ft. 1 in.
Soft blue Lulbegrud clay	5 ft.	28 ft. 7 in.
Light brown limestone, at top of Oldham bed	4 in.	23 ft. 7 in.
Blue clay	6 in.	23 ft. 3 in.
Limestone	6 in.	22 ft. 9 in.
Clay and thin limestone	2 ft.	22 ft. 3 in.
Reddish brown limestone, at base of Oldham bed	3 in.	20 ft. 3 in.
Plum Creek clay and rotten rubble stone	5 ft.	20 ft.
Hard, reddish brown limestone	2 ft.	15 ft.
Horizon with large crinoid beads		
Reddish brown stone, belonging to the Brassfield bed	11 ft.	13 ft.
Massive limestone	2 ft.	2 ft.
Top of Ordovician.		

The differences between these records are due to changes in the exposure, eight years having intervened; the dropping of the limestone layers, owing to the washing out of clay along the roadside, obscures different parts of the sections at different times.

13 CO-NE.—West of Crab Orchard, almost three and a half miles in a direct line from the railroad station, west of a branch of Cedar creek, east of the home of George Boone.

Devonian brachiopods are found in the red soil along the road. Northeast of the house, at the spring, the thickness of the Devonian limestone is about eight and a half feet.

12 CO-NE.—About a quarter of a mile farther west, the following section is exposed, described in descending order:

	Thickness.	Total above base of section.
Devonian limestone.		
Crab Orchard clay shale (Estill and Waco horizons)	20 ft.	47.5 ft.
Massive limestone layer	2 ft.	27.5 ft.
Clay, poorly exposed (Lulbegrud clay)	5 ft. 6 in.	25.5 ft.
Limestone, at top of Oldham horizon	1 ft. 6 in.	20 ft.
Chiefly clay (chiefly Plum Creek clay)	6 ft. 6 in.	18.5 ft.
It is estimated that the base of the Brassfield bed is at least twelve feet farther down, but this part of the section is not exposed		12 ft.

11 CO-NE.—West of Crab Orchard, a little less than four miles west of the railroad station, along the county road, then south along a road leading to Cox gap.

A short distance up this road the contact between the Black slate and the Devonian limestone is seen. The thickness of this limestone is eleven and a half feet. The top is dark brown and has a sort of brecciated appearance. The underlying part contains *Spirifers* and *Atrypa reticularis*. A considerable thickness of the more continuous part of the Crab Orchard clay shale is exposed beneath the Devonian limestone. This was estimated at the time of the visit to be about thirty-five feet thick, but this estimate is probably too large, in view of the carefully measured sections along the county road. This section requires further study. Some fairly well stratified rock is stated in former notes to underlie the Devonian limestone, but no rock of this description is known in the more continuous part of the Crab Orchard shales; possibly it also belongs to the Devonian limestone section, which at this locality may be of unusual thickness.

10 CO-NE.—West of Crab Orchard, about four miles in a direct line from the railroad station, along the county road, west of a branch of Cedar creek, at the home of William Pleasants.

The thickness of the exposed part of the Devonian limestone is six and a half feet. The total thickness is not known. Immediately below, the upper, more continuous Crab Orchard clay shales are exposed, eleven feet thick.

9 CO-NE.—West of Crab Orchard, about four and a quarter miles in a direct line from the railroad station, along the county road, half a mile east of the point at which the road turns sharply northward.

The contact between the Black shale and the Devonian limestone is exposed. The limestone is a very dark grayish blue, like the lower part of the Devonian at Duffin cut. The exposed part is two feet four inches thick, but its total thickness is estimated at five feet. The Devonian limestone rests on clayey shale, seven and a half feet thick, belonging probably to the more continuous part of the Crab Orchard clay shales. Immediately below there is a considerable exposure of the underlying Silurian rocks, but their thickness was not determined.

8 CO-NE.—West of Crab Orchard, about four and a half miles in a direct line from the railroad station, along the county road, west of a point at which the road turns off toward the north.

The base of the Devonian limestone rests upon a layer of reddish brown limestone, two feet thick, which is believed to be the massive layer at the base of the more continuous part of the Crab Orchard clay shales (at top of the Lulbegrud clay). Of the Devonian limestone only the lower part, three feet thick, is exposed, but the total thickness is estimated at, at least, six feet.

7 CO-NE.—West of Crab Orchard, about five miles from the railroad station, along the county road, where the road turns sharply northward, northwest of the home of James Thomas Bailey.

Here the following section is presented, described in descending order:

Black slate.		
Red clay, resulting from the decay of Devonian limestone	1 ft.	
Clay	1 ft.	
Clayey limestone		4 in.
Clay at base of Plum creek horizon	1 ft.	
Massive limestone (base of Crab Orchard division)	1 ft.	6 in.
Limestone, with large crinoid beads in lower part	1 ft.	
Limestone belonging to the Brassfield bed	11 ft.	
Upper beds of Richmond division of the Cincinnatian series of the Ordovician, base not seen	40 ft.	

The Brassfield bed at this locality is quite crinoidal, although the fragments of crinoid stems show that the diameters of the stems are small.

6 CO-NE.—Southeast of Hall Gap station, about one mile from the station, at the school at the road corner a little over half a mile north of James Thomas Bailey, on the county road leading west from Crab Orchard.

The thickness of the Richmond beds exposed here is at least one hundred feet, but the base of the Richmond section is not seen.

5 CO-NE.—South of Hall Gap station about one mile, and

then a quarter of a mile east on the county road leading west from Crab Orchard.

Below the Black slate there is red clay resulting from the decay of limestone, evidently of Silurian age. Ordovician rock is found north of the Black shale exposure, apparently separated from the latter by a fault.

4 CO-NE.—A little over a quarter of a mile westward, north of the road corner, the Black shale rests upon rock too decayed to be recognizable, twelve feet thick. Immediately below, the top of the Ordovician is exposed. The greater part of the decayed rock is believed to belong to the Brassfield bed; in case the Devonian is very thin or absent, it may include all of the Brassfield bed up to the level of the layer containing the large crinoid beads. No silicified Devonian fossils were found in the upper part of this decayed rock. Apparently the Devonian is absent at this locality, and as far west as Neal creek church.

3 CO-NE.—A mile west of the last locality is another exposure showing the base of the Black shale. It is reached by going from Hall Gap station less than a mile south, then almost a mile west to the Hall Gap pike, and finally north along this pike almost half a mile to a point south of the blacksmith shop. The Brassfield bed is exposed along the road north of the shop. But very little of the rock can be seen.

2 CO-NE.—Less than half a mile north of the last exposure, a road turns off from the pike in a southwesterly direction; about half a mile from the pike, a short distance before reaching Hale's well, the base of the Black shale is separated from the top of the Ordovician by an unexposed interval, six feet thick, believed to be formed by the decay of the lower part of the Brassfield bed.

1 CO-NE.—Northwest of Hale's well, about one mile in a direct line, and about three miles south of Stanford, along Neal creek, below Neal creek church.

A short distance east of the church, the Black shale rests on the Brassfield bed. The thickness of the bed preserved at this locality is eight and a half feet. Only the lower part of the bed is present, the top layer with the large crinoid beads and *Whitfieldella cylindrica-subquadrata* not being preserved. As in the sections farther eastward, this lower part of the

Brassfield bed consists of rather massive limestones, the upper part of the exposure being more distinctly bedded. Where less weathered, in the creek, the rock has a bluish color. On the banks, where more weathered, its color is rusty brown. Some of the layers are sparingly crinoidal, but with crinoid stems or segments of stems of small diameter. The lowest layer of the Brassfield bed includes numerous rounded, black pebbles and grains, possibly phosphatic, varying in size from an eighth to a quarter of an inch; a few equal even as much as an inch in diameter. Immediately below, the top of the Ordovician is exposed.

The upper part of the Brassfield bed exposure contains the following fossils: *Orthis flabellites*, *Dalmanella elegantula*, *Strophonella daytonensis*, *Pachydictya bifurcata*, *Halysites catenulatus*, *Favosites niagarensis*, *Cyathophyllum calyculum*. The fossils are most frequent in front of the home of John Raines.

This is the most western exposure of the Brassfield bed on the eastern side of the Cincinnati geanticline, in central Kentucky.

C.—Sections Between Crab Orchard and Stanford, North of the Louisville & Nashville Railroad.

(Figures 3, 4, 5, plate C, page 141.)

22 CO-NE.—At the western end of Crab Orchard, immediately north of the road following the railroad, at the head of a small gully.

Immediately below the Black shale is a layer of brownish rock, eight inches thick, equivalent to the Duffin layer. The underlying rock, two feet thick, contains masses of calcite, minute but distinct grains of quartz, and a few corals. The remainder of the Devonian limestone section is sixteen feet thick; it is well stratified, and can readily be quarried. At the base of this section, for a distance of three feet, the rock is white, solid, and crinoidal. The overlying part is more brownish or dark gray. Silicified corals have weathered out from layers at the top of the Devonian limestone section. The total thickness of the Devonian limestone exposed is about nineteen feet. The contact between the Devonian and Silurian can not

be seen, but is probably immediately below the crinoidal limestone.

In the crinoidal layers at the base of the section, crinoid stems of considerable thickness are found. Immediately above these crinoidal layers, several *Spirifers* with hingelines three and a half inches long were seen. The overlying, well stratified beds are almost devoid of fossils.

21 CO-NE.—West of Crab Orchard station, where the road along the northern side of the railroad turns northward, a little over two miles west of the station.

Along the railroad there is an excellent exposure of the Devonian limestone, sixteen and a half feet thick. The top of the limestone section, immediately below the Black shale, for a thickness of thirty inches, consists of the brecciated or Duffin layer. Beneath this, there is a bluish layer, three feet thick. The lower part, eleven feet thick, consists of well stratified layers of gray, argillaceous-looking limestone. No part of the Devonian limestone section is crinoidal. In general the rock resembles the lower part of the Devonian limestone section at Junction City. Below the Devonian limestone, at the western end of the railroad cut, the Crab Orchard clay shales (Alger clay) are well exposed.

A salt well was formerly worked in the fields southwest of the railroad in the Crab Orchard shales.

31-32 CO-NE.—Northwest of Crab Orchard, about two and a half miles from the center of the village along the pike to Stanford, from the first road east of Cedar creek turning off toward the north, to the road turning off south toward the railroad cut.

At the top of the section, eastward, Devonian corals are found in red soil formed by the decay of the Devonian limestone. Below this red soil the following strata are found, in descending order:

Crab Orchard clay shale (Estill and Waco horizons)..	66 ft.	
Massive limestone layer..............................	1 ft.	3 in.
Chiefly clay (Lulbegrud clay)........................	6 ft.	6 in.
Limestone layers, poorly exposed, base not seen......	2 ft.	

In this section no account is taken of the eastward dip of the strata. The thickness of the Crab Orchard clay shales

(Alger clay) above the massive limestone probably exceeds eighty feet at this locality.

29 CO-NE.—Northwest of Crab Orchard, three miles from center of village, along first road east of Cedar creek turning north from pike to Stanford, about a mile north from the Stanford pike.

The Brassfield bed is exposed at the top of the hill, before descending into the valley of Cedar creek. The upper part of the Richmond division of the Cincinnatian series of Ordovician rocks, ninety feet thick, is found immediately beneath, while farther northward the Maysville bed is exposed, probably separated by a fault. At the top of the Maysville bed *Platystrophia lynx* is present.

28 CO-NE.—Northwest of Crab Orchard, about three miles from the center of the village, east of the crossing of the pike to Stanford over Cedar creek.

North of the pike the following section is exposed, described in descending order:

	Thickness.	Elevation above base of section.
Top of limestone layer.		
Interval	3 ft.	24 ft. 4 in.
Sandy limestone layer, massive	8 in.	21 ft. 4 in.
Poorly exposed, chiefly clay (Plum creek horizon)	5 ft. 6 in.	20 ft. 8 in.
Massive sandy limestone, with large crinoid beads	2 ft.	15 ft. 2 in.
Soft rock, poorly exposed	2 ft.	13 ft. 2 in.
Massive limestone, sandy at top	2 ft.	11 ft. 2 in.
Soft rock, poorly exposed	1 ft. 6 in.	9 ft. 2 in.
Limestone, in layers, belonging to the more massive part of the Brassfield bed	3 ft. 4 in.	7 ft. 8 in.
Massive limestone, belonging to the Brassfield bed	4 ft. 4 in.	4 ft. 4 in.
Top of Ordovician.		

The layer containing the large crincid beads appears to belong to a very constant horizon, at the top of the Brassfield bed. Some of the crinoid beads have a diameter of three quarters of an inch. *Whitfieldella cylindrica-subquadrata* and *Leptaena rhomboidalis* occur in the upper part of the sandy limestone containing the crinoid beads.

In the bottom of Cedar creek valley, on the south side of

the pike, rock is exposed dipping southward at angles varying from twenty to thirty-five degrees.

27 CO-NE.—Northwest of Crab Orchard, about three and a half miles from the center of the village, west of Cedar creek, at the southeastern corner of a hill north of the pike.

Here the following section is exposed, described in descending order:

Massive limestone layer	1 ft.	
Softer rock	3 ft.	6 in.
More massive limestone, belonging to the Brassfield bed	10 ft.	
Ordovician rock of Richmond age, total Richmond section not exposed	70 ft.	

The limestone layer at the top of the section belongs stratigraphically to the *Whitfieldella* horizon, at the top of the Brassfield bed.

23 CO-NE.—Northwest of Crab Orchard, along the pike to Stanford, about an eighth of a mile northwest of Walnut Flats, five miles from the center of Crab Orchard.

Here the layer containing the large crinoid beads, at the top of the Brassfield bed, is exposed. The rock has a strong southward dip. The underlying massive part of the Brassfield bed is exposed, but not in such a manner that the total thickness of this bed can be determined. Faulting appears to have taken place; the rock forms a poor exposure along the northern side of the pike, and only a thickness of six feet can be determined with confidence. However, the original thickness of the bed was probably about ten to thirteen feet, as elsewhere in this part of the State.

24 CO-NE.—Three quarters of a mile southeast of the Walnut Flats, the elevation of the Brassfield bed is fully eighty feet above the exposure of this bed northwest of Walnut Flats. From the more eastern locality, the Clinton or Brassfield bed dips rapidly toward Cedar creek. The probability is that the series of faults which cross the country north of Harmon creek connect with others following the same general direction in the vicinity of the Walnut Flats.

The base of the Brassfield bed, three quarters of a mile southeast of the Walnut Flats (25-CO-NE) is one hundred feet higher than the base of the same bed about half a mile west of

Cedar creek, and 130 feet higher than the base of this bed east of Cedar creek. The layer with large crinoid beads is exposed half a mile west of the creek, west of the culvert.

1 H-SE.—East of Stanford three miles, on the pike to Crab Orchard, west of the point at which the road to Preachersville turns off, north of the pike.

Whitfieldella cylindrica-subquadrata occurs in loose blocks; a little limestone belonging to the Brassfield bed is exposed. There is plenty of chert weathered out from the Devonian limestone immediately above the limestone blocks belonging to the Brassfield bed. The Crab Orchard clay shales appear to have been removed before the deposition of the Devonian.

D.—Sections East and Northeast of Crab Orchard, Chiefly in the Northwestern Corner of the London Quadrangle.

(Figures 2, 3, plate C, page 141.)

1 L-NW.—Southeast of Crab Orchard, a little over a mile from the railroad station, north of the pike north of the railroad, east of a branch of Flades creek, near the home of Bill Monk.

The contact between the Black shale and the Devonian limestone is seen along the pike. The top of the Devonian limestone section consists of a fine-grained, brownish rock, not well exposed, possibly three feet thick, equivalent to the Duffin layer. As usual, it contains very few fossils.

Immediately below, massive, white limestone, eleven feet thick, is exposed. The rock contains numerous specimens of corals, and also a few brachiopods, evidently of Devonian age, however not in a condition favorable for collecting. The lower part of the section, five feet thick, is crinoidal.

The total thickness of the Devonian limestone exposed is about fourteen feet. The contact of the Devonian with the Silurian can not be seen at this locality.

2 L-NW.—East of Crab Orchard, less than two miles in a direct line from the railroad station, reached by following the road to Bill Monk's house, and then turning off northeastward for a distance of three quarters of a mile, at the bluff on the south side of the valley of Dix river.

The Black slate overlies Devonian limestone, fifteen and a half feet thick. About four and a half feet above the base of

the limestone, *Atrypa reticularis*, a large Devonian *Spirifer*, and some corals are found. The limestone occurs in layers one to two feet thick; it is not crinoidal. In the upper part, corals occur.

3 L-NW.—Southeast of Crab Orchard, a little over two miles from the railroad station, along the pike north of the railroad where crossed by a small stream emptying into Dix river, near the home of Mr. Howard.

The contact between the Black shale and the Devonian limestone is seen. Of the Devonian limestone a thickness of about thirteen feet is exposed, but the total thickness may be greater since the contact between the Devonian and Silurian can not be seen at this locality.

The lower part of the section, four feet thick, contains small *Spirifers* and other brachiopods. Immediately above this brachiopod horizon specimens resembling *Taonurus caudagalli* are abundant.

38 CO-NE.—At the northeastern edge of Crab Orchard, about a quarter of a mile from the center of the village, along a road turning off at the school in the northern part of Crab Orchard.

The thickness of the Devonian limestone at this locality is nine feet. The contact with the Black shale is exposed.

5 L-NW.—Northeast of Crab Orchard, about a mile and three quarters in a direct line from the center of the village, at the bluff north of Dix river, half a mile south of Fall Lick creek, south of the road.

The thickness of the Devonian limestone is ten and a half feet. The base of the Devonian rests upon the more continuous part of the clay shales, forming the Estill clay division of the Crab Orchard bed. The top of the Crab Orchard clay shale is about ninety feet above the bed of the creek; since the limestone layers belonging to the Oldham and Brassfield beds are not exposed in the bottom of the creek, the thickness of the more continuous Crab Orchard clay shales is estimated at more thn ninety feet.

6 L-NW.—About three quarters of a mile in a direct line northeast of the last locality, the contact of the Black shale with the Devonian limestone is seen. The locality is about a fifth of a mile east of the point where a road turns off northwest-

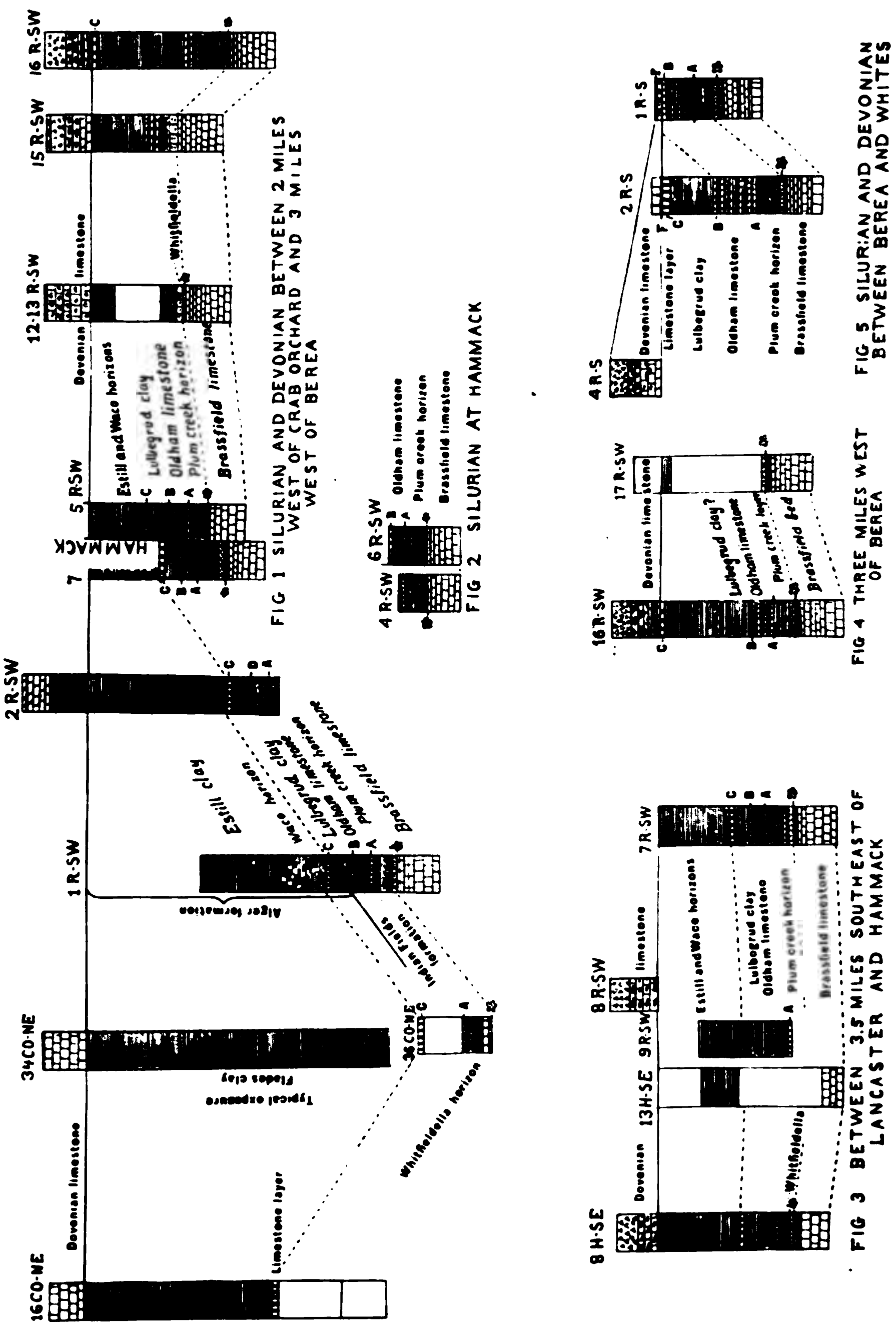
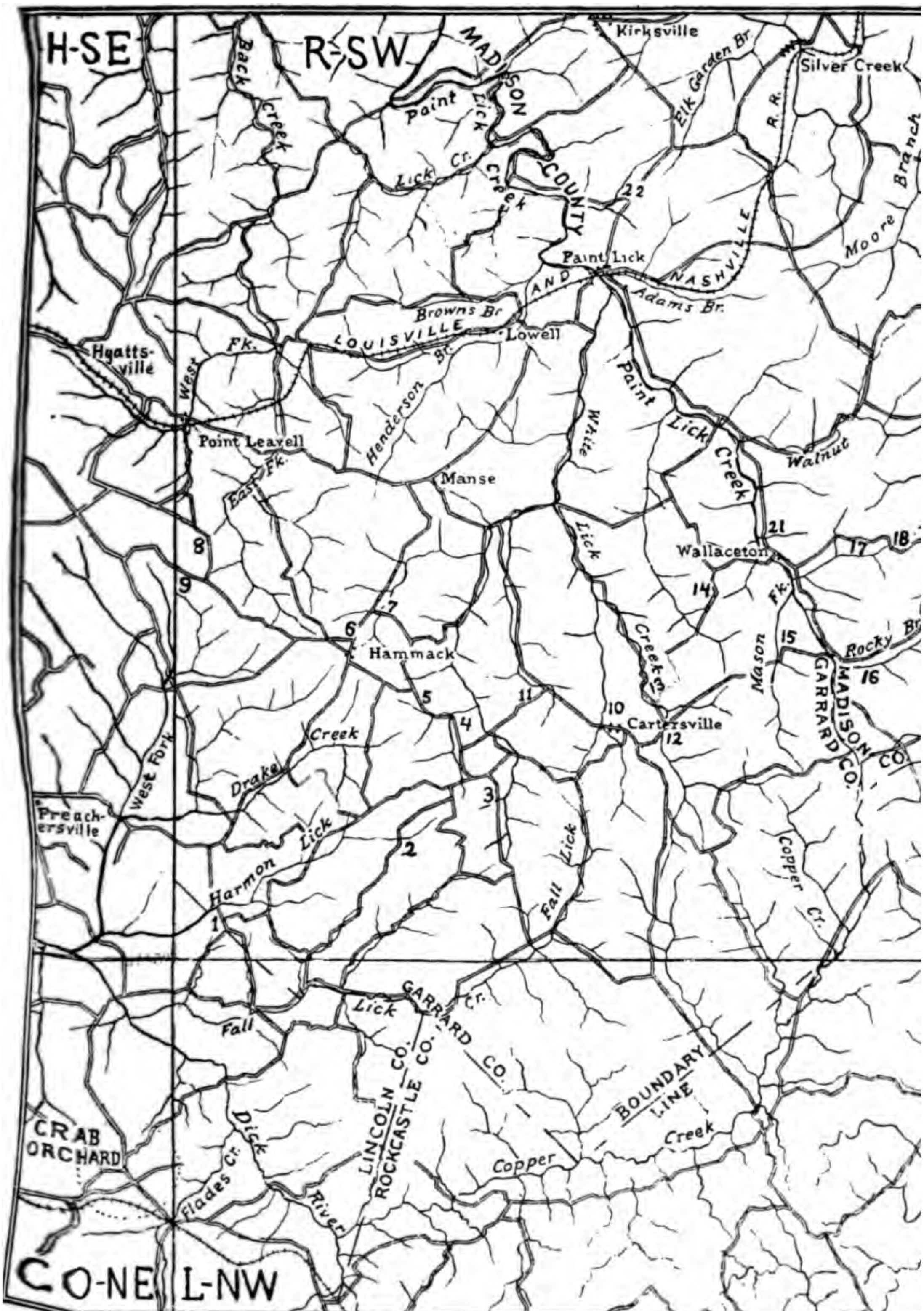


Plate D. Sections of Silurian and Devonian Strata between Crab Orchard and Berea.



Map 2. Map of area between Crab Orchard, Hammack, Berea and Paint Lick.

ward and joins the road following the upper part of Fall Lick creek.

7 L-NW.—About half a mile in a direct line northeast of the last locality, and a quarter of a mile before reaching Fall Lick creek, the thickness of the Devonian limestone is only six feet. Its base is thirty-five feet above the level of the creek, and the interval is occupied by the top of the Estill clay division of the Crab Orchard clay shale. The top layer of the Devonian limestone, four inches thick, has a brecciated appearance, and corresponds to the Duffin layer.

E.—Sections Between Crab Orchard and Berea.

(Figures 2, 5, plate C, page 141; figures 1, 2, 4, plate D, page 154.)

34 CO-NE.—North of Crab Orchard, along the pike to Preachersville, about a mile and a quarter from the center of the village.

The contacts between the Black slate and the Devonian, and between the Devonian and the Silurian are well exposed. The total thickness of the Devonian limestone is twelve feet. At the top of the section, for a distance of four inches, the rock is gray, and has a brecciated appearance. This is equivalent to the Duffin layer. Immediately below, the rock is weathered to a reddish brown, and a number of Devonian corals have weathered out. Northward, in the fields west of the pike, the Alger clay division of the Crab Orchard shales are well exposed. The Clinton or Brassfield limestone is found at the bridge across Dix river.

34-35 CO-NE.—North of Crab Orchard, along the pike to Preachersville, about a mile and a quarter from the center of the village.

The contact between the Devonian limestone and the Alger clay division of the Crab Orchard clay shales is seen along the pike. In a gully along the western side of the pike, the Crab Orchard shale is exposed for a distance of sixty-five feet below the Devonian contact. At the base of the section a salt well goes still deeper into the Crab Orchard shale. The total thickness of the Crab Orchard shales is unknown, but the top of the section is about seventy-six feet above the level of the bridge across Dix river.

36 CO-NE.—At the bridge, a section consisting of limestone alternating with clay rock, five feet thick, is exposed. At the top of this section there is a layer of solid limestone, ten inches thick, and at the bottom are two layers of limestone having a total thickness of about eight inches, but the middle part contains considerable clay, and probably is equivalent to the Plum creek clay layer. Below this section there is a layer of massive limestone, a foot and a half thick. The underlying limestone has a more sandy appearance, and contains large crinoid beads and specimens of *Whitfieldella cylindrica-subquadrata.* This *Whitfieldella* layer is a very constant horizon and forms the top of the more continuous limestone section, the Brassfield bed, in this part of Kentucky.

North of the bridge, a thick layer of limestone is found ten feet above the level of the bridge. About a quarter of a mile north of the bridge, where the steeper part of the hill begins, this massive limestone layer is well exposed about thirty-nine feet above the level of the bridge. The rock apparently dips southward. It was not struck by the salt well at the foot of the Crab Orchard shales in the section here described. It is probable that the total thickness of the Crab Orchard shales above this massive limestone, including the Estill and Waco horizons, equals at least one hundred feet. The distance of this limestone above the *Whitfieldella* layer can not be determined at this locality with certainty.

37 CO-NE.—About half way between Crab Orchard and Preachersville, along the pike, between the bridges over Dix river and Drake creek, the Clinton or Brassfield bed is exposed at several localities west of the pike. Faulting has taken place, with the downthrow on the southern side. There is evidence of faulting also north of Drake creek, where the Brassfield bed is about one hundred feet above Drake creek. No study of the direction of these faults or the amount of throw of the beds affected has been made as yet.

4 H-SE.—Several faults occur also less than a mile northeast of that part of the pike from Crab Orchard to Preachersville which lies between the bridges over Dix river and Drake creek. These faults lie about three miles southwest of Hammack, and may be reached by following the road east from Preachersville. At the northern end of the series of faults, on

the southern side of Drake creek, along the steep ascent of the hill, there is a considerable exposure of the Maysville or Middle division of the Cincinnatian series of rocks, but only about half of the Richmond division is exposed. South of the first line of faulting the Clinton with part of the clay division of the Crab Orchard bed is seen. South of a second fault (5 H-SE) the Devonian limestone and the Black shale are exposed. Farther south, along a third fault, the Brassfield bed occurs at a higher level, on the south side of the fault, then the Devonian limestone on the northern side. Many problems of structural geology are presented by these and other faults in this vicinity, but these must wait for solution until the more detailed work of the survey can be taken up.

1 R-SW.—North of Crab Orchard, fully three miles in a direct line, on the pike to Hammack and Richmond, south of Harmon creek.

Here the following section is seen, described in descending order:

	Thickness.	Elevation above base of sections.
Crab Orchard clay shale, belonging to the Estill and Waco horizons, with lower 11 feet of section containing small rock fragments, but no fossils........	33 ft.	62 ft. 2 in.
Massive limestone layer..............................	1 ft.	29 ft. 2 in.
Chiefly clay, Lulbegrud horizon.........................	5 ft.	28 ft. 2 in.
Thin limestone and clay, Oldham bed..................	5 ft.	23 ft. 2 in.
Limestone layer.......................................	8 in.	18 ft. 2 in.
Considerable clay with limestone interbedded, Plum creek horizon..................................	5 ft.	17 ft. 6 in.
Massive limestone....................................	1 ft. 6 in.	12 ft. 6 in.
Horizon of large crinoid beads.		
Limestone layers belonging to the massive Clinton or Brassfield horizon.................................	11 ft.	11 ft.
Ordovician contact.		

The contact of the Crab Orchard shales with the Devonian is not seen at this locality.

2 R-SW.—About three miles in a direct line southwest of Cartersville, and two and a half miles south of Hammack, on the headwaters of Harmon creek; reached by going from Cartersville northwest one mile, then southwest a little over a mile

and a quarter, south a third of a mile, west a quarter of a mile, south an eighth of a mile, and finally southwest nearly a mile. The exposure is on the southern side of Harmon creek.

Black shale.		
Brownish rock, like that of Duffin layer.............	1 ft.	
Streak of Black shale.		
Devonian limestone, with the top resembling the brecciated or Duffin layer........................	6 ft.	
Soft material, weathered back, poorly exposed, with a streak of clay................................	5 ft.	6 in.
Bluish clay rock, Devonian, weathering brownish and shaly, unlike Devonian rock elsewhere...........	4 ft.	6 in.
Crab Orchard clay shale (Estill and Waco beds), well exposed	37 ft.	
Massive limestone layer..............................	1 ft.	3 in.
Chiefly clay (Lulbegrud clay), possibly including strata belonging to the Oldham horizon.................	10 ft.	
Thin limestone interbedded with clay, believed to be a short distance above the 5-foot clay layer, above the *Whitfieldella* bed. Not determined.		
Bed of creek.		

3 R-SW.—Seven and a half miles in a direct line southwest of the railroad station at Berea, about a mile and a half southwest in a direct line from Cartersville; reached by going from Cartersville northwest about a mile along the pike, then southwest almost a mile, southeast nearly a third of a mile, southwest about a third of a mile, and finally south of the last fork of the road about a third of a mile where the road crosses a small stream, two and a half miles in a direct line southeast of Hammack.

Here considerable cherty Devonian limestone is exposed.

4 R-SW.—Two miles west of Cartersville in a direct line; reached by going from Cartersville one mile northwest along the pike, then a mile and a quarter southwest, and a third of a mile northwest, east of Brandy Spring branch. (Fig. 2, Plate of sections, D.)

Black shale.	
Brecciated dark brown or Duffin layer................	8 ft.
Fault.	
Poorly exposed, limestone interbedded with clay....	7 ft.
Limestone with large crinoid beads, *Triplecia ortoni*, and *Cyathophyllum calyculum*.	
Limestone forming the Brassfield bed................	9 ft.
Top of Ordovician.	

5 R-SW.—About half a mile northwest of the last locality, and a mile southeast of Hammack, at the sharp angle in the road near the point where the road crosses a small stream entering Brandy Spring branch, half a mile east of the home of Robert Parsons. The section begins at the meeting of three roads northwest of the main exposure.

Black shale, weathered to clay.		
Massive brecciated or Duffin layer, weathered sc as to be almost unrecognizable.		
Devonian chert abundant, showing presence formerly of the Devonian limestone, with chert.		
Crab Orchard clay shale (Estill and Waco beds)....	15 ft.	
Limestone, lower part softer........................	1 ft.	3 in.
Clay shale (Lulbegrud clay)..........................	5 ft.	
Limestone, fairly hard (top of Oldham horizon)......		8 in.
Limestone layers interbedded with clay..............	4 ft.	4 in.
Limestone, fairly solid..............................		8 in.
Limestone interbedded with clay (equivalent to Plum creek clay horizon...............................	4 ft.	4 in.
Limestone with large crinoid beads..................		6 in.
Limestone forming the Brassfield bed................	9 ft.	
Top of the Ordovician.		

6 R-SW.—Northeast of Hammack, at the northeastern angle of a triangle made by various roads, at the northern edge of the hill where the old part of the road, now abandoned, descends into the valley of a western branch of Brandy Spring creek, south of Doc. Hunt. (Fig. 2, Plate of Sections, D.)

Rotten limestone, belonging to the Oldham horizon...	1 ft.	
Clay shale and soft clayey rock.....................	3 ft.	
Hard limestone......................................		6 in.
Clay with rotten limestone layers (equivalent to Plum creek clay horizon)..............................	5 ft.	
Limestone with *Whitfieldella* and large crinoid beads..		6 in.
Hard limestone with large crinoid beads, one seven-eighths of an inch across, also with *Leptaena rhomboidalis*, *Favosites*, and *Cyathophyllum calyculum*...	1 ft.	
Rusty brown limestone, forming the Brassfield bed....	8 ft.	
Top of Ordovician.		

7 R-SW.—About half a mile north of Hammack, on the road to Manse, south of the home of Wood Walker, along a road crossing the stream and then going eastward up the hill.

	Thickness.	Total thickness to base of section.
Devonian chert fragments.		
Crab Orchard clay shale (Estill and Waco beds)......	20 ft.	48 ft. 1 in.
Solid white limestone..............................	1 ft. 3 in.	28 ft. 1 in.
Soft blue clay (Lulbegrud clay)......................	4 ft.	26 ft. 10 in.
Limestone layers (top of Oldham limestone).........	10 in.	22 ft. 10 in.
Clayey limestone.................................	1 ft.	22 ft.
Solid limestone..................................	1 ft.	21 ft.
Softer limestone layers............................	1 ft. 2 in.	20 ft.
Solid limestone..................................	1 ft.	18 ft. 10 in.
Clayey rock and soft clayey limestone (top of Plum creek clay horizon)...........................	3 ft.	17 ft. 10 in.
Harder clayey rock...............................	6 in.	14 ft. 10 in.
Soft rock...	6 in.	14 ft. 4 in.
Limestone	8 in.	13 ft. 10 in.
Softer stone......................................	6 in.	13 ft. 2 in.
Limestone with large crinoid beads..................	1 ft. 10 in.	12 ft. 8 in.
Softer limestone...................................	1 ft. 2 in.	10 ft. 10 in.
Reddish brown limestone, forming the Brassfield bed.	9 ft. 8 in.	9 ft. 8 in.
Top of Ordovician.		

12-13 R-SW.—Five and a half miles southwest of the railroad station at Berea, nearly three quarters of a mile directly east of Cartersville, east of White Lick creek.

Phosphatic nodules, 1-2 inches long, at base of the Waverly.		
Black shale, no account taken of the dip, the amount of which is not known...........................	102 ft.	
Sandy rock...		6 in.
Brown brecciated or Duffin layer, apparently faulted and otherwise disturbed so that its original thickness is uncertain...............................	11 ft.	
Crab Orchard bed, upper part consisting of lower part of Alger clay, probably with Plum creek clay bed at base....................................	19 ft.	
Thin limestone interbedded with clay................	4 ft.	
Solid limestone with *Whitfieldella*....................	1 ft.	6 in.
Limestone with large crinoid beads, *Cyathophyllum calyculum*, and *Zaphrentis daytonensis*...........		6 in.
The remainder of the Brassfield bed consists of reddish brown limestone.......................	12 ft.	
Top of Ordovician.		

10 R-SW.—At the western end of Cartersville, north of the pike, along a stream. There is a considerable exposure here of the brecciated or Duffin layer and of the cherty Devonian limestone, apparently underlaid by well bedded rock belonging to the Devonian; beneath this level there is greenish clay.

11 R-SW.—About a mile northwestward from Cartersville, along the road which turns off from the pike toward the southwest, the Clinton or Brassfield bed is exposed along the roadside.

15 R-SW.—About four miles southwest of the railroad station at Berea, on the eastern side of Mason Fork, near the home of Charles Baker.

Black shale.		
Dark gray clay rock		4 in.
Very cherty rock	1 ft.	
Brecciated or Duffin layer, but very cherty	4 ft.	
Next layers exposed farther south.		
Devonian limestone with chert	4 ft.	
Dark gray, well-bedded limestone	3 ft.	
Crab Orchard clay	10 ft.	
Thin-bedded limestone, with *Orthis flabellites*, at base of Waco horizon		6 in.
Section with chiefly clay in the upper part, but with limestone interbedded in lower part	10 ft.	
Sandy limestone, *Whitfieldella* layer	2 ft.	
Horizon with large crinoid beads.		
Reddish brown limestone, belonging to the Brassfield bed	12 ft.	

16 R-SW.—Three miles in a direct line southwest of the railroad station at Berea, along Rocky branch, west of the home of Sam Todd. (Fig. 4, Plate D.)

Black shale.		
Brecciated or Duffin layer, with parts of crinoid stems and cyathophylloid corals	5 ft.	6 in.
Devonian limestone with coarse chert	3 ft.	
Gray limestone with very little chert	3 ft.	6 in.
Devonian limestone, crinoidal		6 in.
Massive Silurian limestone, rusty brown (possibly layer at base of Waco horizon)	1 ft.	
Poorly exposed	23 ft.	
Clay with several heavy beds of limestone interbedded in upper part	10 ft.	

Reddish brown stone, coarse..........................	6 in.
Limestone with *Whitfieldella cylindrica-subquadrata*..	10 in.
Limestone with large crinoid beads, *Cyclonema*, and *Cyathophyllum calyculum*..........................	6 in.
The remainder of the Brassfield bed was not measured here, but was estimated at about................	12 ft.

17-18 R-SW.—Two and a half miles west of the station at Berea, a mile and a half east of Wallaceton. (Fig. 4, Plate D.)

The layer, at the base of the Waverly, with phosphatic nodules an inch long is eighty-five feet above the Devonian limestone, but no account of the dip is taken here. In the same manner the base of the Black shale is found thirty-five feet above the layer with large crinoid beads, at the top of the Brassfield bed. In the gully, south of the road, the thickness of the Brassfield bed, up to the top of the layer with large crinoid beads, is twelve feet.

F.—Sections Between Hammack and Lancaster.

(Figure 3, plate D, page 154; map 1, page 140.)

8 R-SW.—Nearly two miles west of Hammack and two miles south of Point Leavell, about a quarter of a mile north of the Flat Woods church, along the new road from Hammack to Point Leavell, above a spring north of a farm house.

Black shale.		
Brown rock corresponding to the brecciated or Duffin layer	5 ft.	6 in
Devonian limestone, very cherty.....................	7 ft.	6 in.
Crab Orchard clay shale, full thickness not known (probably belonging to the Estill and Waco beds).	20 ft.	

9 R-SW.—Along the road from the Flat Woods church to Lancaster, a short but not recorded distance west of the church, the following section was exposed:

Crab Orchard clay shale, top not exposed (probably chiefly the Waco horizon)........................	11 ft.	
Solid limestone layer................................	1 ft.	3 in.
Poorly exposed, chiefly clay (Lulbegrud clay at top)...	11 ft.	
Limestone	1 ft.	

13 H-SE.—A short distance farther west, along the same road, east of a branch west from the home of Peter Spainhower.

Loose fragments of Devonian material.		
Interval unknown	11 ft.	
Crab Orchard clay shale	10 ft.	
Interval	23 ft.	
Massive limestone belonging to the lower part of the Brassfield bed	5 ft.	6 in.
Greenish clay, top of the Ordovician.		

6 H-SE.—The base of the Brassfield bed is exposed also at the Lawson chapel, about half a mile south of the Lancaster road, southwest of the home of Peter Spainhower.

8 H-SE.—About three and a half miles southeast of Lancaster, on the road to Hammack, northwest of the home of James M. Anderson.

Black shale.		
Precciated or Duffin layer, fossiliferous	5 ft.	6 in.
Devonian limestone, very cherty	5 ft.	6 in.
Crab Orchard clay shale (probably Estill and Waco beds)	22 ft.	
Solid limestone	1 ft.	3 in.
Chiefly clay (Lulbegrud clay at top)	8 ft.	
Solid limestone	1 ft.	
Clayey limestone interbedded with clay (equivalent to Plum creek clay)	3 ft.	
Limestone	1 ft.	
Horizon with large crinoid beads, at top of Brassfield bed.		
Limestone in layers	2 ft.	
Massive limestone	7 ft.	
Top of Ordovician.		

Platystrophia lynx occurs about a mile farther west, just east of the main crossing over Gilbert creek.

About a mile and a half southwest of the home of James M. Anderson, northeast of Sweeney Morgan, Devonian rock with Devonian corals occurs.

G.—Sections Between Berea and Whites.

(Figure 5, plate D, page 154; map 3, page 167.)

1 R-S.—Four miles north of Berea, half a mile south of White station.

Argillaceous beds at base of Black shale.		
Devonian, blue argillaceous, gritty limestone with fish remains		3 in.
Limestone containing much calcite, in some places in considerable blotches, possibly corresponding to the Devonian rock below the layer with fish remains southwest of Elliston, east of Moberly	1 ft.	3 in.
Limestone, at Oldham horizon, apparently contains poor specimens of *Stricklandinia*	1 ft.	3 in.
Blue clayey shale		10 in.
Limestone interbedded with considerable clay	6 ft.	
Chiefly clay with layers of clay rock interbedded, corresponding to the 5-foot layer of clay forming the Plum creek horizon in more northeastern sections.	5 ft.	
Limestone with large crinoid beads and *Whitfieldella cylindrica-subquadrata* near base	1 ft.	4 in.
Limestone, heavy and thinner beds, interbedded with clay	9 ft.	
Massive limestone, at base of the Brassfield bed	2 ft.	2 in.
Top of Ordovician.		

There is probably a fault a short distance north of the Silurian outcrop since the nearest outcrop of *Platystrophia lynx* is only forty-five feet below the base of the Silurian.

2 R-S.—Less than three miles north of Berea, where the railroad crosses over a deep valley.

Near Berea the dark brown brecciated rock, the Duffin layer, overlies the cherty Devonian limestone. This was not seen in the section here described.		
Devonian limestone	2 ft.	4 in.
Layer with fish remains		1 in.
Massive reddish brown limestone; may be the 2-foot layer in the Crab Orchard shale	2 ft.	
Crab Orchard clay shale (Lulbegrud clay), only the upper part, 4 feet thick, well exposed	11 ft.	
Limestone interbedded with clay in upper part of section	18 ft.	
Limestone layer, with large crinoid beads, *Orthothetes*, *Platystrophia daytonensis*, *Heliolites subtubulata*, and *Cyathophyllum calyculum*	1 ft.	
Limestone, with thin clay layers at top, belonging to the Brassfield bed	10 ft.	

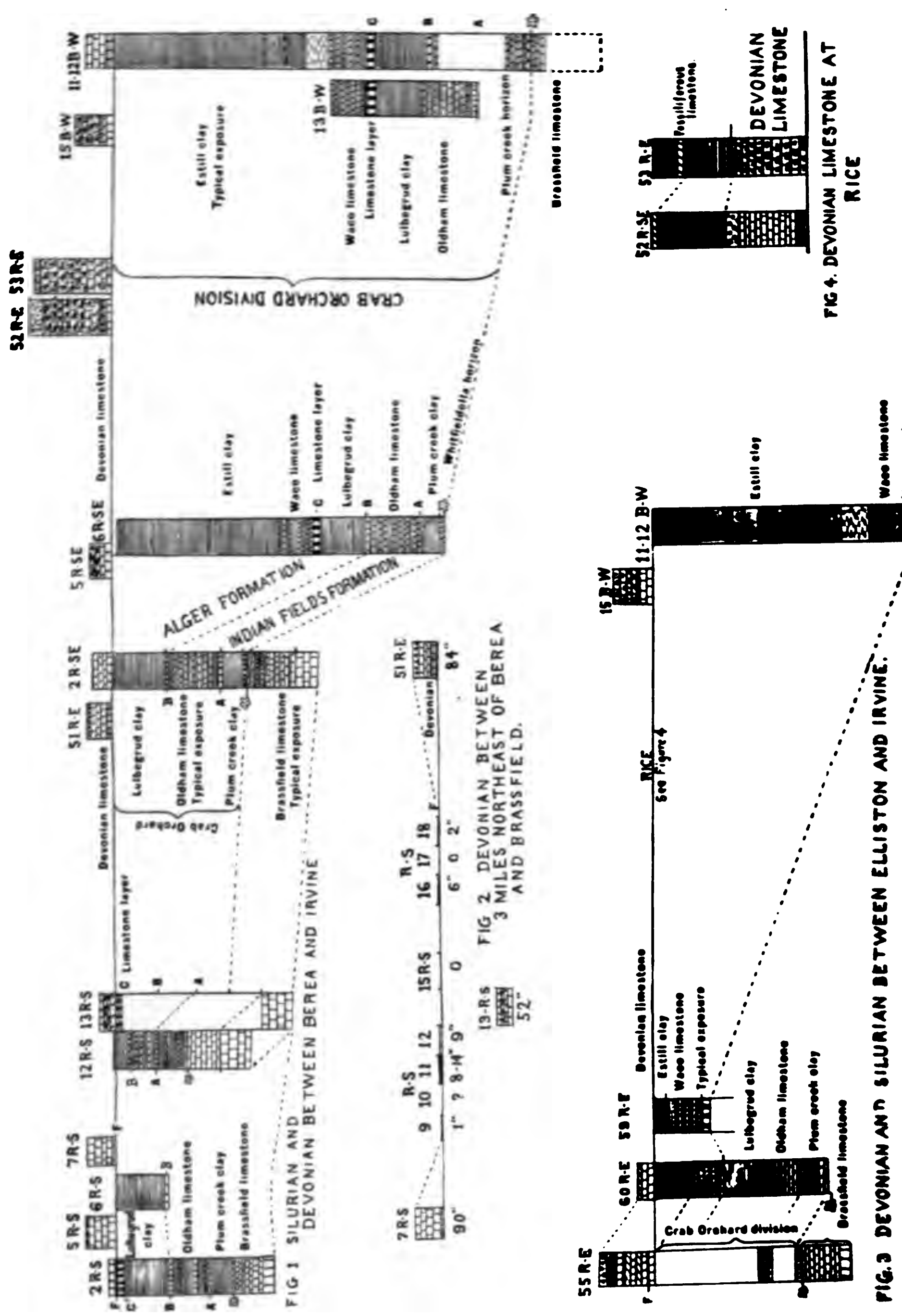
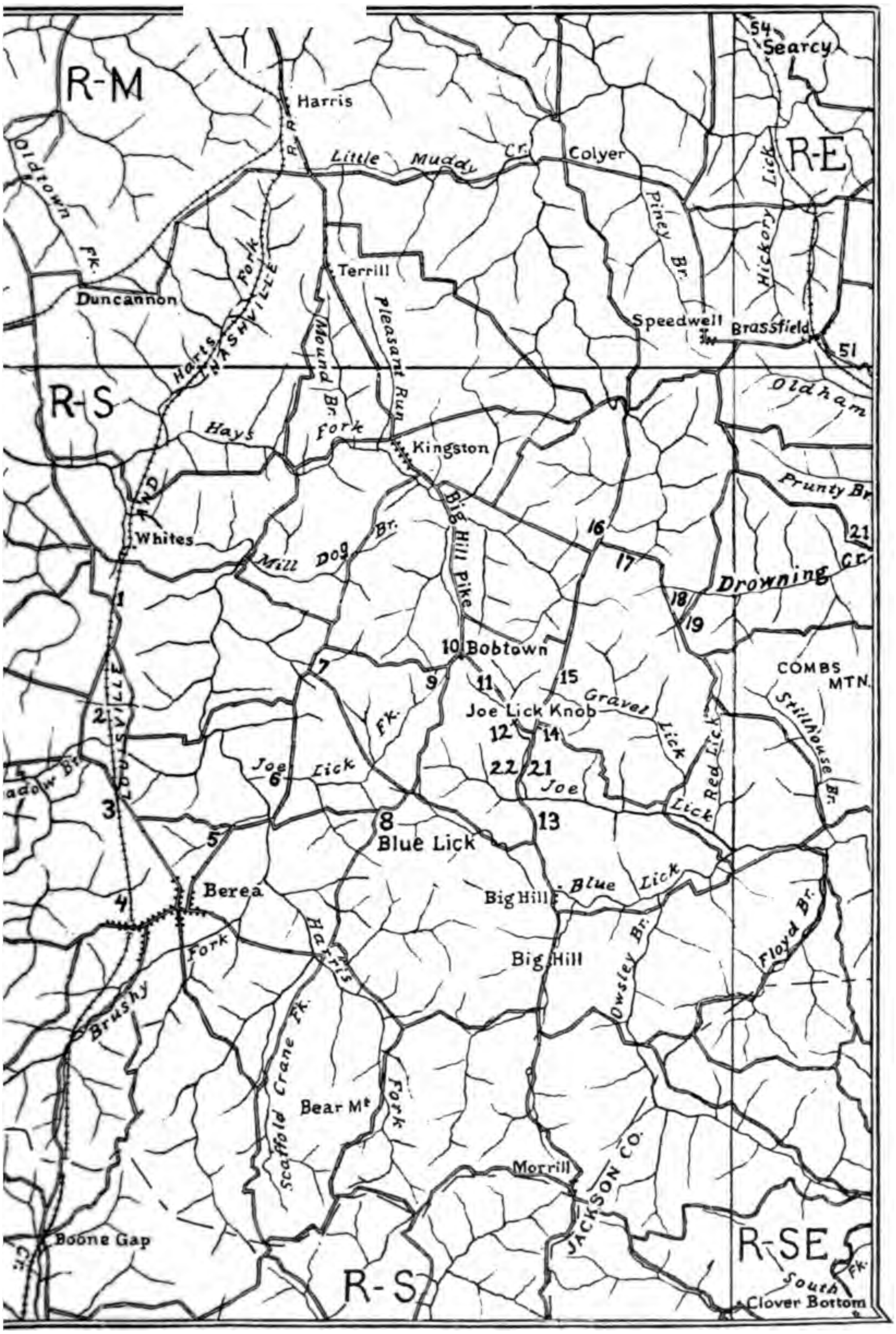


Plate B. Sections of Silurian and Devonian Strata between Berea, Brassfield and Irvine.



Map 3. Map of area between Berea and Brassfield.

4 R-S.—Half a mile north of Berea, along the railroad.

Black shale.	
The brecciated, dark blue Duffin layer................	5 ft.
Devonian limestone, very cherty near the top..........	8 ft. 6 in.

H.—Sections Between Berea and Brassfield.

(Figures 1, 2, plate E, page 166.)

5 R-S.—About a mile northeast of the center of Berea, on the Kingston turnpike.

Black shale.	
Interval.	
Chert containing cyathophylloid corals...............	4 in.
Devonian limestone, upper part with parts of crinoid stems	8 ft.

6 R-S.—About two miles northeast of Berea, where the road crosses Joe Lick, a quarter of a mile west of the road, south of the home of Bever Terrell.

Devonian limestone.	
Crab Orchard clay shale (probably Lulbegrud clay)...	13 ft.
Reddish brown limestone with calcite forming nodular masses.	

7 R-S.—Four miles northeast of Berea, on the I. C. Baker farm.

South of the house there appears to be an exposure of the Brassfield bed. The thickness of the bed appears to be ten and a half feet, and of this the lower part, seven feet thick, is massive limestone. A fault appears to extend north of here. On the north side of the fault, north of the house, at about the same level as the Clinton or Brassfield bed, the Devonian is seen. It slants strongly toward the southwest. The top of the exposure, six and a half feet thick, consists of gray Devonian limestone. The base, one foot thick, weathers to a more shaly rock, contains tiny black nodular masses, and apparently corresponds to the layer with fish remains.

9 R-S.—About four miles northeast of the center of Berea, an eighth of a mile northeast of the New Liberty church, and half a mile south of the Bobtown store.

The Devonian limestone, at the cross roads and also half a mile farther west, is reduced to a thin sandy layer, half an

inch thick, believed to be equivalent to the layer which elsewhere contains fish reamins.

10 R-S.—At the north end of Bobtown, north of the home of Dave Garrett. A single massive layer of Brassfield rock, four feet thick, is seen west of the road. Farther south, at Joe Creekmore's house, in the well, the Black shale rests almost directly on the Crab Orchard shale (probably the Lulbegrud clay). The Devonian limestone was not identified here. The interval between the base of the Black shale at the Creekmore well and the top of the massive bed north of the home of Dave Garrett is sixteen feet six inches, but this interval, in the well, is occupied altogether by clay shale, suggesting the presence of a fault here between the two exposures.

11 R-S.—Half a mile southeast of Bobtown, near the house owned by Mat Moody, the Devonian limestone, under the Black shale has a thickness of eight inches. The Crab Orchard shale (probably the Lulbegrud clay) is seen below.

Farther southeast, where the road crosses a stream, the thickness of the Devonian limestone is fourteen inches.

12 R-S.—Four and a half miles northeast of the center of Berea, about a mile southeast of Bobtown, at the end of the Jackson hollow.

Argillaceous beds in the lower part of the Black shale.		
Devonian limestone		9 in.
Chiefly clay, belonging to the Crab Orchard clay shale, with layers of thin limestone included in the lower part which is equivalent to the Oldham limestone.	11 ft.	
Limestone		9 in.
Chiefly clay (Plum creek clay)	5 ft.	
Limestone	1 ft.	
Clay, limestone and clay, in descending order		9 in.
Red sandy limestone with *Whitfieldella cylindrica-subquadrata* common	1 ft.	
Horizon with large crinoid beads common.		
Limestone, in thinner beds than the layers below	9 ft.	
Massive limestone forming the lower part of the Brassfield bed	8 ft.	

13 R-S.—At Mat Moody's store, about two miles and a quarter southeast of Bobtown, about a mile east of Joe Lick knob.

Black shale.		
Grayish rock	1 ft.	4 in.
Devonian limestone, very cherty		10 in.
Gray limestone with a little chert		10 in.
Grayish Devonian limestone	1 ft.	4 in.
Reddish brown limestone, Silurian	1 ft.	
Reddish brown limestone	1 ft.	
Interval estimated at	38 ft.	6 in.
(The top of this interval is formed by the Lulbegrud clay.)		
Top of massive limestone forming the lower part of the Brassfield bed.		

14 R-S.—South of the Log cabin school-house, about a quarter of a mile north of Mat Moody's store.

There is a fault here.

Chiefly clay.	
Interval consisting chiefly of limestone interbedded with clay	6 ft.
Massive limestone forming the lower part of the Brassfield bed	8 ft.
Clay rock, upper part of Richmond division.	

15 R-S.—About half a mile north of Mat Moody's store, on the north side of Gravel Lick creek.

Black shale.		
Clay rock layers at base of the Black shale	4 ft.	
Devonian limestone absent.		
Limestone, probably of Silurian age		8 in.
Lulbegrud clay shale	12 ft.	
Thin limestone interbedded with clay; Oldham limestone.		

Farther north there is a fault with Black shale on the south side and Ordovician rock on the north.

16 R-S.—About two and a half miles north of Mat Moody's store, south of the home of Joe Gibbs.

White Irvine clay.		
Black shale.		
Hard clay rock in Black shale.		
Interval	2 ft.	6 in.
Sandy Devonian rock		6 in.
Crab Orchard clay (probably Lulbegrud clay).		

17 R-S.—A quarter of a mile east of the last locality, three miles northeast of the top of Joe Lick knob.

Black shale.	
Crab Orchard limestone layer........................	3 in.
Crab Orchard clay shale (probably Lulbegrud clay).	

18 R-S.—Half a mile southwest of the last locality, reached by going from Brassfield west one mile, then south three miles in a direct line, and finally northwest a distance of almost half a mile, where the road crosses the head of Drowning creek. The exposure is on the southeastern side of the crossing.

Solid clay rock in the Black shale....................	4 ft.	
A thin layer of Black shale.		
Devonian limestone with fish remains................		2 in.
Reddish brown limestone, Silurian....................	1 ft.	2 in.
Crab Orchard clay shale (Lulbegrud clay)............	10 ft.	
Stream bed.		

The rock above the layer with fish remains may be equivalent to some of the layers identified as Devonian limestone elsewhere. Some distance farther up the Black shale contains argillaceous rock layers.

19 R-S.—Less than half a mile southeast of the last locality, at the forks of the road, at the locality known as the Bear Wallow, White Irvine clay, with rusty brown sandy material in it, is exposed.

I.—Sections Between Irvine and Brassfield.

(Figures 1, 4, plate E, page 166; map 4, page 173.)

11 B-W.—North of Irvine, north of the springs about three quarters of a mile, from the junction of the White Oak creek road and the road to Calloway creek, northeastward, up the hill.

The following section is exposed, described in descending order:

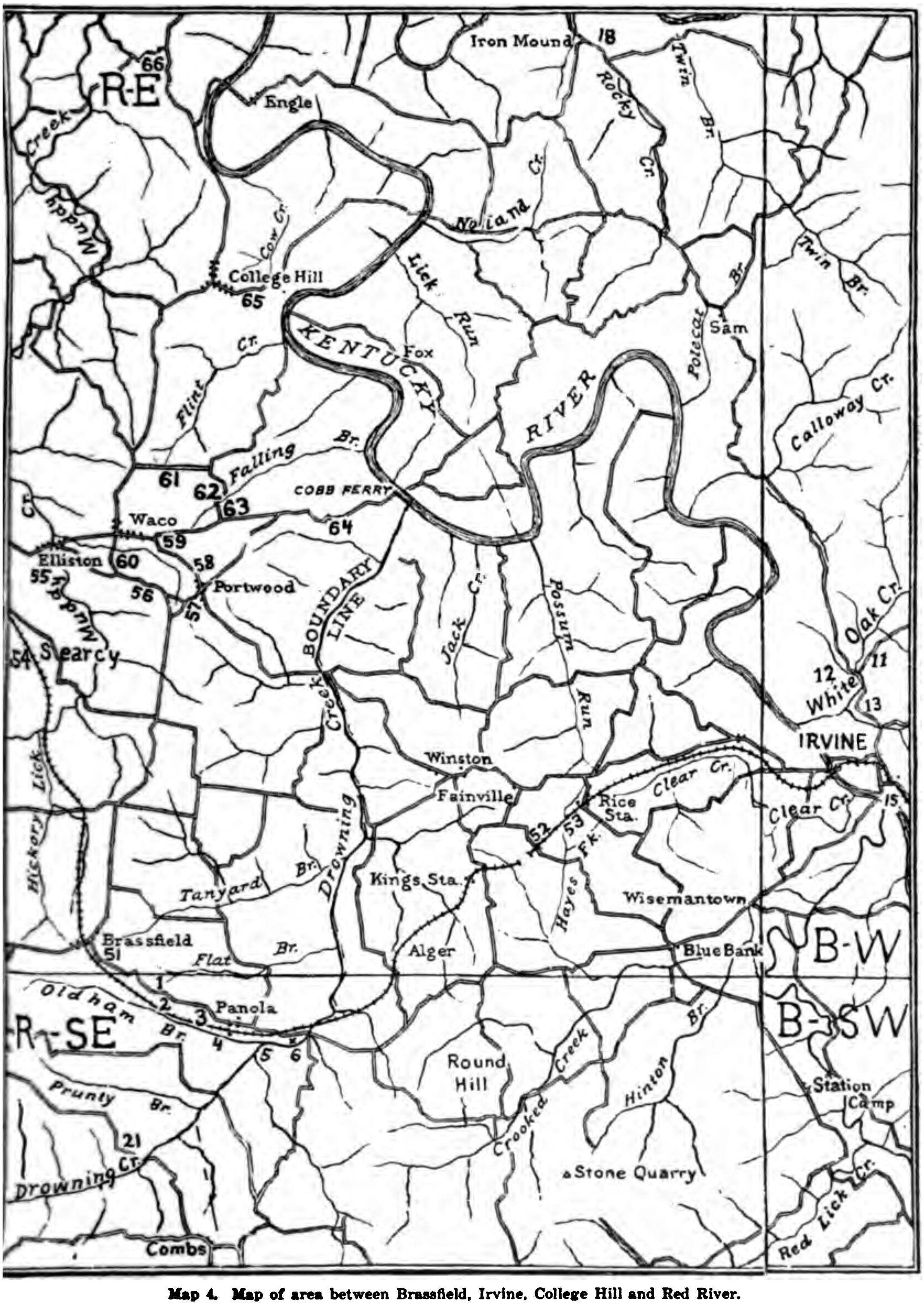
Black shale.		
Devonian limestone, base of section not well exposed.	7 ft.	6 in.
White Estill clay, with thin argillaceous shale in lower 7.5 feet of section................................	60 ft.	6 in.
Waco bed, clay with limestone.......................	10 ft.	

Solid brownish limestone, a layer of wide distribution at this level	2 ft.	
Lulbegrud clay	14 ft.	6 in.
Interval occupied by Oldham limestone, and Plum creek clay poorly exposed	27 ft.	6 in.
Coarse-grained limestone, wave-marked at top		8 in.
Whitfieldella cylindrica-subquadrata horizon, at top of the Clinton or Brassfield bed.		

Immediately below the layer with *Whitfieldella cylindrica-subquadrata* and the large crinoid beads, are several feet of limestone belonging at the top of the Brassfield bed. These contain *Calymmene niagarensis, Cyclonema daytonensis, Rhynchotrema scobina, Leptaena rhomboidalis, Plectambonites transversalis, Dalmanella elegantula, Orthis flabellites, Rhinopora frondosa, Phylloporina angulata,* and *Cyathophyllum calyculum.*

12 B-W.—North of Irvine, about half a mile north of the springs, from the point where the road first reaches White Oak creek northwestward up the hill along a private road past the home of James F. Harris.

Black shale.		
Devonian limestone, weathered to a red clay with cherty fragments.		
White Crab Orchard clay shale, top of Estill clay, poorly exposed	11 ft.	6 in.
White Crab Orchard clay shale, well exposed, with comparatively few sandy shale fragments	30 ft.	
White clay, with small and very thin sandy shale fragments	11 ft.	
Clay with considerably sandy shale of gray color, and with thin brownish limestone, equivalent to the Waco layer, but without fossils here. A layer of rotten brownish limestone, 6 inches thick, occurs 5 feet 6 inches above the base, and below this level most of the section consists of white clay	16 ft.	6 in.
Solid brownish limestone, a layer of wide distribution at this level	2 ft.	
White clay, at top belonging to the Estill layer; the lower half with thin interbedded limestone belonging to the Oldham horizon	25 ft.	
Rotten limestone in thin layers, also belonging to the Oldham horizon	5 ft.	6 in.
Whitfieldella cylindrica-subquadrata layer not exposed here, but estimated to occur below the last-mentioned limestone a distance of	12 ft.	
Bottom of creek is about 12 feet lower.		



Map 4. Map of area between Brassfield, Irvine, College Hill and Red River.

13 B-W.—North of Irvine, north of Estill Springs about a quarter of a mile, along the road before reaching White Oak creek.

Clay with numerous fragments of thin limestone, equivalent to the Waco layer, with fossils........	10 ft.	
Massive limestone layer..............................	2 ft.	
Clay, forming the Lulbegrud layer....................	13 ft.	
Thin limestone interbedded with clay equivalent to the Oldham limestone............................	12 ft.	
Immediately below or only a few feet lower should occur the 5-foot layer of clay equivalent to the Plum creek clay layer.		

15 B-W.—West of the railroad station at Irvine, half way to the railroad bridge, along the railroad.

Black shale, with argillaceous rock layers in lower 6 feet of section.		
Cherty Devonian limestone..........................	6 ft.	6 in.
Darker, more sandy appearing rock, with *Ambocoelia umbonata* common at top........................		8 in.
Massive ferruginous brown limestone.................	3 ft.	3 in.
Crab Orchard clay shale, belonging to the Estill clay horizon.		

Along Station camp creek, south of Irvine, no exposures of the Devonian limestone thicker than seven feet were noticed.

16 B-W.—Two miles southeast of Irvine, opposite the mouth of Big Doe creek.

Black shale is exposed down to the river's edge.

53 R-E.—West of Irvine about four miles in a direct line, west of Rice Station, along the railroad.

Black shale, the top of the section not exposed......	40 ft.	
Thin clayey rock layers in Black shale................	4 ft.	
Clayey	2 ft.	6 in.
Solid argillaceous limestone, with Devonian corals and *Atrypa reticularis*............................	2 ft.	
Shale, some of it argillaceous and of a more gray color	13 ft.	
Brownish limestone, probably equivalent to the Duffin layer which has a brecciated appearance..........	1 ft.	4 in.
Devonian limestone with chert; probably 7 to 10 feet of the section consists of chert..................	20 ft.	
Crab Orchard clay, belonging to the Estill clay horizon, indurated at top.		

52 R-E.—West of Irvine about four and a half miles in a direct line, three quarters of a mile southwest of Rice Station, east and west of the tunnel.

Black shale with alum salts oozing out at base.		
Clayey layers in Black shale, equivalent to the clayey layers west of Clay City	10 ft.	
Black shale with fossiliferous clay rock at base	9 ft.	
Interval, exposed but not described in field notes	18 ft.	6 in.
Hard, brownish rock, equivalent stratigraphically to the brecciated or Duffin layer	4 ft.	
Very cherty Devonian limestone	16 ft.	
Bluish argillaceous rock	2 ft.	
Brownish rock, without chert	1 ft.	
Crab Orchard clay shale, belonging to the Estill clay horizon.		

6 R-SE.—East of Panola about a quarter of a mile, from the creek to the western end of the railroad cut.

Crab Orchard clay shale, belonging to the Estill clay horizon, the top not exposed	45 ft.	88 ft. 6 in.
Clay and limestone, equivalent to the Waco layer, with fossils	9 ft.	43 ft. 6 in.
Massive limestone. This layer has a very wide distribution	2 ft.	34 ft. 6 in.
Lulbegrud clay	12 ft. 6 in.	32 ft. 6 in.
Clay with many intercalated layers of thin limestone, especially toward the top, belonging to the Oldham limestone horizon	15 ft.	20 ft.
Clay, equivalent to the Plum creek clay layer	5 ft.	5 ft.
Limestone within one or two feet of the *Whitfieldella* horizon.		

4 R-SE.—Southwest of the railroad station, west of the road, the very massive unfossiliferous layer at the bottom of the Brassfield limestone section is well exposed. In some of the immediately overlying layers, *Heliolites subtubulata* is present. Southwestward, up the hill (5 R-SE.), Devonian limestone, six feet thick, is seen. The upper half of this limestone is very cherty.

2 R-SE.—Between eight and ten miles southwest of Irvine in a direct line, north of the railroad between Panola and Brassfield.

	Thickness	Total from base of section.
Black shale.		
Devonian limestone, gray	5 ft.	62 ft. 3 in.
Chiefly clay, belonging to the Lulbegrud clay horizon of the Crab Orchard clay shale bed, poorly exposed.	18 ft.	57 ft. 3 in.
Thin limestone and thin clay shale interbedded, near top of Oldham limestone	6 ft. 6 in.	39 ft. 3 in.
Medium and thin limestone layers interbedded with thin clay	3 ft. 9 in.	32 ft. 9 in.
Chiefly clay, with thin limestone interbedded	2 ft.	29 ft.
Limestone	1 ft.	27 ft.
Plum creek clay, with very little thin limestone	5 ft.	26 ft.
Ferruginous limestone, with *Cyathophyllum calyculum*.	1 ft. 6 in.	21 ft.
Whitfieldella cylindrica-subquadrata and large crinoid bead horizon, forming top of Brassfield limestone.		
Irregularly bedded limestone with very little clay, containing *Orthothetes fissiplicata*	2 ft.	19 ft. 7 in.
Clay forming from half to three-fourths of the section, with interbedded limestone; containing *Calymmene vogdesi, Cyclonema daytonensis, Rhynchotrema scobina, Leptaena rhomboidalis, Plectambonites transversalis, Platystrophia reversata, Dalmanella elegantula Rhinopora frondosa, Aspidopora parmula,* and *Cyathophyllum calyculum*	3 ft. 4 in.	17 ft. 7 in.
Limestone, irregular bedded, with a little thin clay forming partings between some of the limestone layers	8 ft. 3 in.	14 ft. 3 in.
Very massive limestone, at base of Brassfield bed, more bluish than the overlying layers, apparently unfossiliferous	6 ft.	6 ft.
Top of the Ordovician.		

3 R-SE.—At another locality along the railroad between Panola and Brassfield the following section was seen:

Limestone, with large crinoid beads and *Whitfieldella cylindrica-subquadrata*	2 ft.
Reddish purple, sandy rock, soft, at top of Brassfield bed	1 ft.
Clayey rock	1 ft.
Well bedded limestone	10 ft.
Massive, more bluish layer, unfossiliferous	6 ft.
Ordovician.	

1 R-SE.—North of the county road from Panola to Brassfield, about a mile and a quarter from Panola, along the hill-slope in a field northeast of a large farm house, the following section was recorded. It is evident that some disturbance has taken place in the rocks, since this exposure is apparently much thinner than that measured immediately south of this locality, north of the railroad.

Black shale.		
Devonian rock.		
Clay, poorly exposed	15 ft.	
Limestone		3 in.
Clay, poorly exposed	5 ft.	6 in.
Limestone		6 in.
Clay interbedded with rubble limestone	9 ft.	
Interval, chiefly clay, poorly exposed	10 ft.	
Solid limestone, belonging to the Brassfield bed	10 ft.	

The rock appear to be much tilted and the section irreliable.

51 R-E.—Beneath the overhead bridge across the railroad, south of the station at Brassfield, and thence eastward along the railroad. This is the most carefully measured section in this vicinity.

Black shale.		
Brownish rock belonging to the Duffin layer, appearing brecciated	1 ft.	6 in.
Devonian limestone, more brown than the underlying layer of limestone, with a few fossils	4 ft.	
Bluish argillaceous Devonian limestone	1 ft.	6 in.
Lulbegrud clay	15 ft.	
Thin layers of limestone	2 ft.	
Oldham limestone, consisting of thicker layers with comparatively little clay intercalated. *Stricklandinia* occurs at the top	9 ft.	
Elkins limestone interbedded with more clay	3 ft.	4 in.
Plum creek clay	3 ft.	3 in.
Thin clayey limestone interbedded with clay, also belonging to the Plum creek horizon	1 ft.	10 in.
Massive limestone with *Whitfieldella*. The top, for a distance of 6 to 9 inches, is oolitic	2 ft.	6 in.
More frequently bedded part of Brassfield limestone, with large crinoid beads at top (Clinton)	12 ft.	3 in.
Very massive limestone at base of Brassfield limestone	6 ft.	
Ordovician.		

J.—Sections Between Moberly, Waco, and the Kentucky River.

(Figure 3, plate E, page 166; map 4, page 173.)

55 R-E.—Half a mile southeast of Moberly, a stream crosses the railroad track. A short distance east of the railroad, in the bed of the stream, the base of the Black shale is seen. The following section is exposed, down the stream:

Black shale.	
Limestone	2 ft.
Interval, poorly exposed	7 ft.
Limestone with abundant chert; a few large crinoid stems, and *Spirifer euryteines*	5 ft.
Base of Devonian limestone not exposed here.	

The relation of this section to that southwest of Elliston, along the same branch of Muddy creek, has not been determined.

55 R-E.—East of Moberly a mile and a half, southwest of Elliston, on the western side of Muddy creek.

	Thickness	Total thickness above base of sect.
Black shale.		
Massive rock, equivalent to the brecciated or Duffin layer	2 ft. 6 in.	70 ft. 8 in.
Solid limestone, in 3 to 4 inch layers	1 ft. 2 in.	68 ft. 2 in.
Sandy, gray rock, weathering back	1 ft. 4 in.	67 ft.
Massive rock, with crinoid stems	2 ft.	65 ft. 8 in.
Rotten limestone layer	6 in.	63 ft. 8 in.
Gray massive limestone	1 ft. 6 in.	63 ft. 2 in.
Gray sandy rock	1 ft. 2 in.	61 ft. 8 in.
Gray massive rock	1 ft. 6 in.	60 ft. 6 in.
Gray, well-bedded, sandy limestone	2 ft.	59 ft
Horizon with small black nodules, with fish remains.		
Gray, well-bedded, sandy rock forming base of Devonian section	2 ft.	57 ft.
Not exposed; probably Waco, Lulbegrud, and part of Oldham horizons of the Crab Orchard bed	29 ft.	55 ft.
Interval, chiefly clay with thin limestone layers at top, probably almost entirely clay in lower half, including part of Oldham limestone and all of Plum creek clay	10 ft. 6 in.	26 ft.
Sandy limestone, with ferruginous layer immediately above. Sandy layer contains *Whitfieldella cylindrica-subquadrata* and large crinoid beads	1 ft. 6 in.	15 ft. 6 in.
Thinner bedded limestone with large crinoid beads at top, forming top of Brassfield bed	3 ft. 6 in.	14 ft.
Solid, well-bedded limestone belonging to the Brassfield bed	7 ft.	10 ft. 6 in.
Solid massive rock, unfossiliferous	3 ft. 6 in.	3 ft. 6 in.
Top of Ordovician.		

Immediately below the *Whitfieldella* layer occur *Orthis flabellites, Leptaena rhomboidalis,* and *Cyathophyllum calyculum.* The well bedded limestones, forming the main body of the Brassfield bed, weather to a rusty brown color.

60 R-E.—South of Waco, along the road leading southward up the hill.

Fissile Black shale.		
Soft argillaceous rock		6 in.
Black shale with an argillaceous layer near the middle.	6 ft.	3 in.
Argillaceous rock	1 ft.	3 in.
Devonian limestone, not cherty	3 ft.	9 in.
Estill clay	11 ft.	
Waco limestone with fossils	7 ft.	6 in.
Limestone layer		10 in.
Lulbegrud clay	13 ft.	
Thin-bedded Oldham limestone and clay	5 ft.	6 in.
Rather heavy Oldham limestone with clay	3 ft.	6 in.
Chiefly clay, Plum creek horizon	6 ft.	
Sandy limestone with *Whitfieldella*	2 ft.	6 in.
Limestone with large crinoid beads	1 ft.	
Level of creek.		

59 R-E.—Half a mile east of Waco, north of the corner at which the road to Cobb ferry leaves the road to Bybeetown, or Portwood.

Black shale.		
Devonian limestone.		
Crab Orchard clay shale, fossiliferous, chiefly the Waco layer	13 ft.	6 in.
Massive limestone layer	2 ft.	
Distance down to *Whitfieldella* layer is estimated from the exposure south of Waco at	28 ft.	

The fossiliferous part of the Crab Orchard clay shale, here called the Waco layer, extends from the massive two-foot layer of limestone to a point ten feet higher up.

64 R-E.—East of Moberly, about five miles in a direct line, west of Cobb ferry, along the road.

Black shale.	
Brownish rock with brecciated appearance, equivalent to the Duffin layer, with fragments of crinoid stems at top, and with *Favosites* and some chert near the base	5 ft.

Devonian limestone, very cherty	16 ft.	6 in.
Interval formed chiefly by the Lulbegrud clay division of the Crab Orchard shales	20 ft.	
Clay with considerable limestone interbedded, including the lower part of the Oldham and all of the Plum creek bed	11 ft.	6 in.
Limestone layers, ferruginous at base	2 ft.	6 in.
Whitfieldella layer		6 in.
Well-bedded limestone, with thicker beds at base of section, belonging to the Brassfield bed	14 ft.	
Massive limestone, unfossiliferous, forming base of the Brassfield bed	3 ft.	
Clay shale, forming upper part of the Richmond division of the Cincinnatian series of Ordovician rocks. Thin streaks of limestone, apparently the result of concretionary action, in the lower half, and near the base the clay includes more irregular small concretionary rubble	54 ft.	
Blue limestone at top, and clayey limestone at base of section, including *Hebertella sinuata*, *Platystrophia*, *Streptelasma rusticum-canadensis*; at base of section, also *Strophomena retusta*	9 ft.	
Clayey rock with *Streptelasma rusticum-canadensis* at various levels	5 ft.	
Not exposed, probably sandy clay shale	26 ft.	6 in.
Sandy clay rock	10 ft.	
Not exposed, probably sandy clay rock	53 ft.	
Dense, blue limestone layer	1 ft.	
Sandy shale with thin blue limestone layers	2 ft.	
Dense, blue limestone	1 ft.	
Sandy rock, at river's edge	5 ft.	

The dense blue limestone near the base of this section is believed to belong at the top of the Maysville division.

Calapoecia cribriformis was found loose in the Irvine sand along the road, west of top of this section.

62 R-E.—About a mile and a third in a direct line northeast of Waco, north of Falling branch, opposite the home of Tom Curtis, at Moore spring.

Black shale, fissile above, earthy toward the base.		
More solid rock		9 in.
Argillaceous shale	3 ft.	
More solid argillaceous rock	3 ft.	
Argillaceous shale	11 ft.	6 in.
Devonian limestone, with comparatively little chert	18 ft.	
Crab Orchard clay shale, probably near the base of the Estill clay.		

65 R-E.—Northeast of Moberly about five miles in a direct line, almost three quarters of a mile east of College Hill, along the road to Fox.

Black shale.		
Devonian limestone, poorly exposed	6 ft.	6 in.
Blue, well-bedded limestone, with several chert layers.	3 ft.	6 in.
Devonian limestone, crincidal, poorly exposed	2 ft.	6 in.
Base of Estill clay and all of Waco horizon, the latter with fossils	14 ft.	
Limestone layer		8 in.
Lulbegrud clay	14 ft.	
Oldham limestone, estimated at	11 ft.	
Plum creek clay with thin limestone, 10 inches thick, interbedded at base	4 ft.	3 in.
Whitfieldella layer	1 ft.	
Layer with large crinoid beads, at top of Brassfield limestone.		
Limestone interbedded with clay	4 ft.	6 in.
Well-bedded limestone with very little clay, top layer wave-marked	7 ft.	6 in.
Massive base of Brassfield limestone	1 ft.	4 in.
Argillaceous rock, forming upper part of Richmond division of the Cincinnatian; whitish, clayey	33 ft.	
Argillaceous rock, with one specimen of *Strophomena sulcata* at top and with more frequent specimens of this species at the bottom	8 ft.	6 in.
Argillaceous rock	53 ft.	
Horizon with *Strophomena* and *Streptelasma*, too imperfect for identification.		
Earthy thin-bedded clay	20 ft.	
Interval poorly exposed	70 ft.	
Limestone, blue, fine-grained, witn small *Orthoceras* and *Lophospira*, near top of Maysville division...		3 in.
Clay rock		9 in.
Massive, blue, fine-grained limestone with worm-borings and small specimens of *Lophospira*	1 ft.	6 in.
Shaly, thin-bedded rock, without *Pl. lynx*	18 ft.	6 in.
Platystrophia lynx not rare	6 ft.	6 in.
Platystrophia lynx comparatively rare	15 ft.	
Platystrophia lynx comparatively common	10 ft.	
Not well exposed	15 ft.	
Bed of rivor.		

66 R-E.—Three and a half miles north of College Hill, where the road for Union City turns off toward the southwest.

Black shale.		
Brownish rocks resembling the Duffin layer	1 ft.	
Black shale		9 in.
Brownish rock with numerous specimens of *Taonurus cauda-galli*	3 ft.	
Brownish rock	1 ft.	3 in.
Limestone with abundant chert	4 ft.	
White crinoidal limestone with corals	2 ft.	6 in.
Light brown massive Devonian limestone, with a few *Spirifers* within 2 feet of the base	10 ft.	
Silurian clay, probably at base of Estill division of the Crab Orchard, poorly exposed.		

Taonurus cauda-galli is considered the result of tracings made by some form of marine worm, lodging in some vertical hole and sweeping the upper end of its body in all directions for food.

67 R-NE.—Five and a half miles north of College Hill, on the old Bloomingdale road. Along the road south of a house; north and south of a deep valley.

Black shale.		
Devonian limestone, upper part cherty	17 ft.	6 in.
Interval	5 ft.	
Clay with thin limestone containing Waco fossils	5 ft.	6 in.
Clay, no fossils noticed	5 ft.	6 in.
Limestone, with strong fucoidal markings		6 in.
Lulbegrud clay	8 ft.	6 in.
Oldham limestone with *Stricklandinia* at top	7 ft.	6 in.
Plum creek clay	2 ft.	6 in.
Limestone		3 in.
Clay		6 in.
Limestone, base of Plum creek clay		6 in.

The exposures are poor.

K.—Sections Between Indian Fields, Vienna, and Lulbegrud Creek.

(Figures 1, 2, 3, 4, plate F, page 184; map 5, page 185.)

7 R-NE.—Two miles west of Indian Fields, reached by going south along the road from the station, then turning west along the Winchester pike about a mile and a half. At the Curry bridge over Howard creek.

The *Whitfieldella cylindrica-subquadrata* layer at the top of the Brassfield layer is exposed at the top of the hill. The thickness of the Brassfield bed was not determined, but the base of this bed is estimated to be about 145 feet above the highest layers containing *Platystrophia lynx*, although the actual measured interval was about 120 feet. The rocks dip eastward.

8 R-NE.—Half a mile southwest of Indian Fields, north of the home of John Goff, and thence south up the hill south of the pike. (Fig. 4, Plate F.)

Base of the Waverly clay, with traces of phosphatic rock.		
Black shale	40 ft.	
Clay		12 in.
Black shale	1 ft.	8 in.
Clay		8 in.
Black shale	1 ft.	6 in.
Clay		8 in.
Black (Huron) shale	82 ft.	
Sandy rock with worm borings	1 ft.	6 in.
Devonian limestone	1 ft.	10 in.
Sandy rotten stone	1 ft.	6 in.
Ferruginous brown limestone with fish plates		11 in.
Layer with fish remains and tiny black nodules		5 in.
Estill clay division of the Crab Orchard clay shale.		

1 B-NW.—South of Indian Fields about a quarter of a mile, along the road, where it crosses a small branch of Lulbegrud creek, crossing the M. H. Hisle farm. (Fig. 4, Plate F.)

Black shale.		
Solid brownish Devonian limestone	1 ft.	8 in.
Layer with fish remains	1 ft.	
Clay, with Waco fossils in the lower half	20 ft.	
Limestone layer		.9 in.
Lulbegrud clay	13 ft.	
Top of Oldham limestone with *Stricklandinia* in bed of branch	2 ft.	

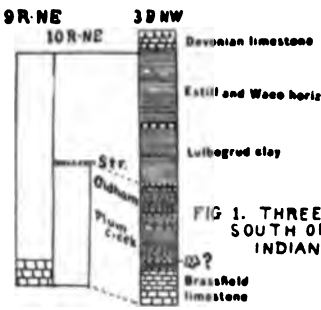


FIG 1. THREE MILES SOUTH OF INDIAN FIELDS

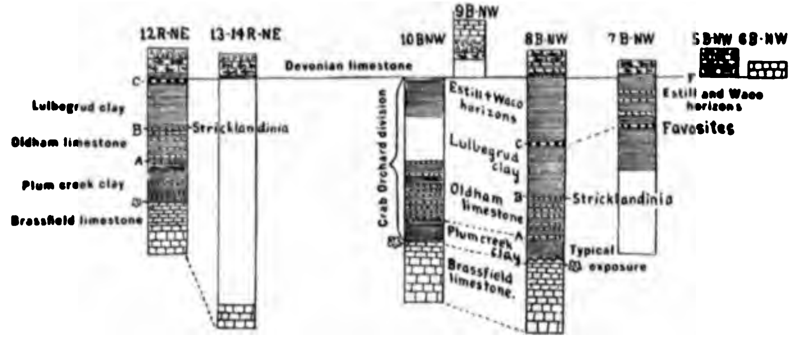


FIG 2. SILURIAN AND DEVONIAN BETWEEN JT. ELKINS AND CLAY CITY

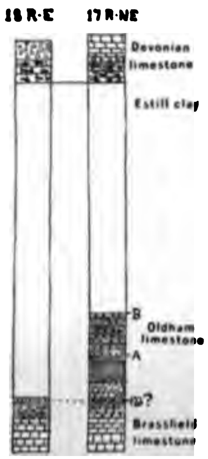


FIG 3. NEAR VIENNA.

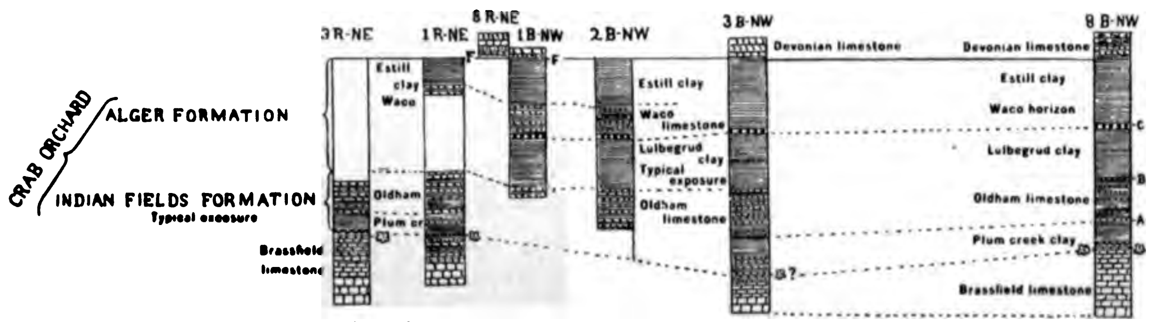
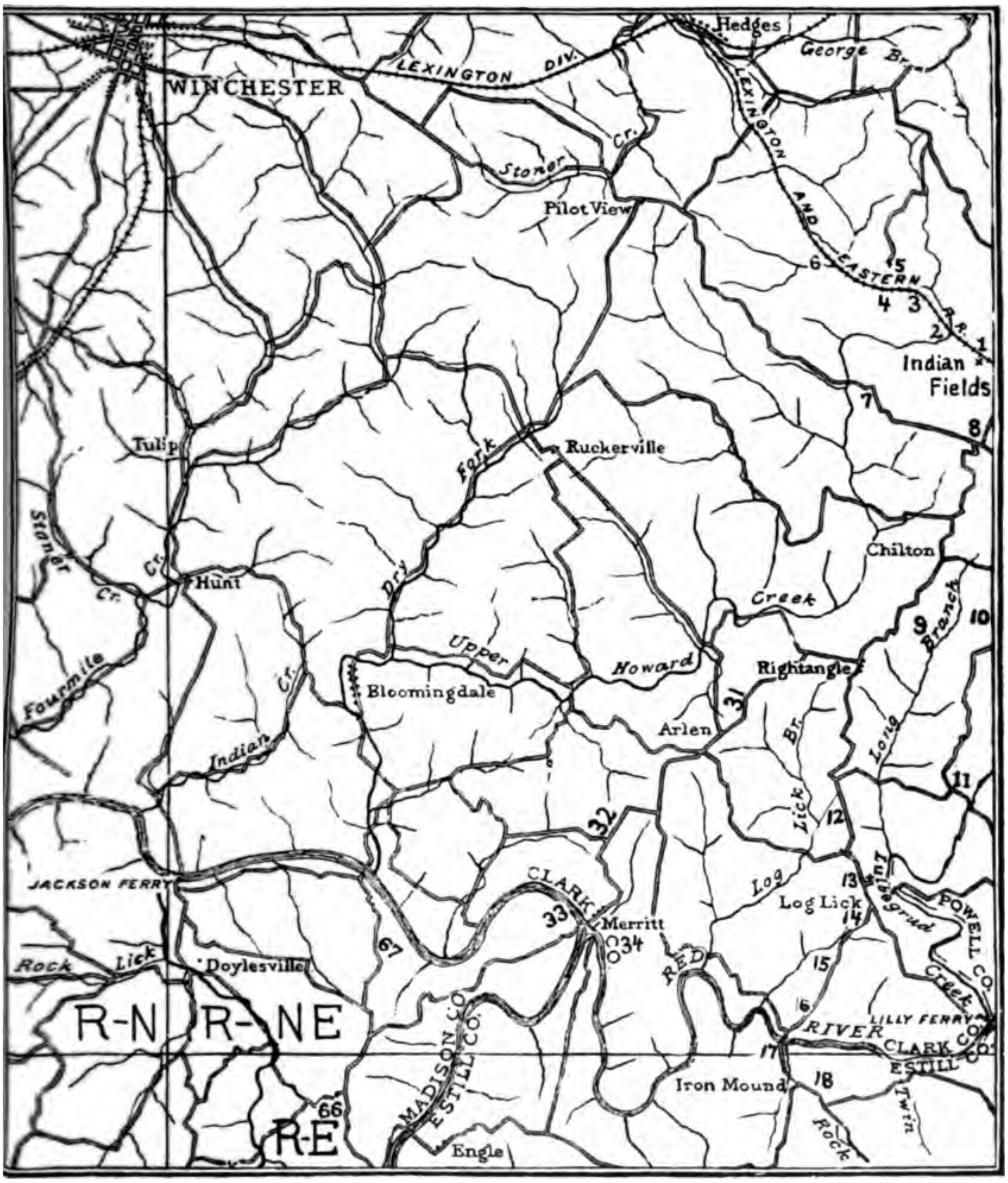


FIG 4 SILURIAN AND DEVONIAN BETWEEN 2 MILES NORTWEST OF INDIAN FIELDS AND 3 MILES SOUTHWEST OF CLAY CITY.

Plate F. Sections of Silurian and Devonian Strata between Indian Fields, Clay City and Vienna.



Map 5. Map of area between Red River, Indian Fields and Winchester.

The Oldham limestone contains also *Heliolites subtúbulata*, *Halysites catenulatus*, *Cyathophyllum calyculum*, and *Zaphrentis daytonensis*.

2 B-NW.—About a mile southeast of Indian Fields along the railroad, and then south along a road toward Lulbegrud creek; a short distance east of the home of Brownlow Bruner. (Fog. 4, Plate F.)

Black shale.		
Brown rock, Devonian.		
Estill clay	12 ft.	
Clay with thin limestone layers and Waco fossils	8 ft.	3 in.
Limestone		9 in.
Lulbegrud clay	13 ft.	
Top of Oldham limestone, with *Stricklandinia*	5 ft.	6 in.
Interval	6 ft.	
Lulbegrud creek.		

3 B-NW.—South of Indian Fields about two and a half miles in a direct line, at Abbott's mill, on Lulbegrud creek. (Fig. 1, Plate F.)

Black shale.		
Devonian limestone with worm borings	3 ft.	9 in.
Rusty brown limestone	1 ft.	3 in.
Probably the layer with fish remains		6 in.
Crab Orchard clay shale, Estill and Waco horizons	19 ft.	
Reddish brown limestone	1 ft.	
White clay, Lulbegrud horizon	7 ft.	6 in.
Limestone layer.		
White clay	7 ft.	6 in.
Clay with reddish brown limestone at various levels, Oldham and Plum creek horizons	23 ft.	6 in.
Reddish brown limestone with *Rhinopora frondosa*, *Zaphrentis daytonensis*, and *Cyathophyllum calyculum*. Owing to faulting, the top of the Clinton or Brassfield bed is not well exposed at this point, and the full thickness of this bed is probably greater	5 ft.	4 in.
Reddish brown limestone, with bluish argillaceous rock at the base. Containing *Cyclonema daytonensis*, *Leptaena rhomboidalis*, and *Clathropora frondosa*	3 ft.	7 in.
Soft blue clay shale	2 ft.	

9 R-NE.—South of Indian Fields about two and a half miles in a direct line, about half a mile southeast of Chilton, on the Old Billy Snowden farm near the headwaters of Long branch, west of the creek. (Fig 1, Plate F.)

Here the distance from the base of the Silurian to the base of the Devonian limestone is sixty-two feet.

10 R-NE.—On the eastern side of Long branch, on the Morgan Eubanks farm, *Stricklandinia* occurs about thirty feet above the base of the Silurian.

11 R-NE.—About four and a half miles south of Indian Fields, at Crow ford, on Lulbegrud creek.

The base of the Silurian here is seventy-three feet above the creek.

12 R-NE.—About five miles west of south from Indian Fields, on the road to Vienna, along the run crossing the road south of the home of J. T. Elkins. The section is much obscured by soil and by the dip of the rock, the strata being exposed at distant points along the run and along the road. (Fig. 2, Plate F.)

Fissile Black shale.		
Argillaceous rock, equivalent to the Duffin layer......	3 ft.	
Devonian limestone, with chert......................	3 ft.	9 in.
Not exposed, probably clay..........................	1 ft.	9 in.
Massive reddish brown limestone, probably the 2-foot layer at the base of the Waco horizon of other sections	1 ft.	
Blue clay, probably the Lulbegrud layer..............	12 ft.	
Brownish limestone, *Stricklandinia* layer at top of Oldham limestone..................................		4 in.
Chiefly clay, some interbedded limestone..............	5 ft.	
Solid brown limestone...............................		6 in.
Soft clay, Plum creek horizon........................	8 ft.	
Clayey limestone....................................		2 in.
Chiefly clay, with limestone interbedded..............	5 ft.	6 in.
Horizon with large crinoid beads; cross-bedded limestone at top of Brassfield bed...................		6 in.
Well-bedded limestone...............................	8 ft.	
Massive limestone, unfossiliferous....................	6 ft.	6 in.
Top of Ordovician.		

13 R-NE.—Six miles west of south of Indian Fields, along the road to Vienna, along the road east of Log Lick church. (Fig. 2, Plate F.)

Black shale.		
Brownish rock, brecciated in appearance, belonging to the Duffin layer	2 ft.	
Massive, cherty Devonian limestone	4 ft.	
Probably clay, poorly exposed		6 in.
Solid layer of limestone, brownish red, probably the 2-foot layer at the base of the Waco horizon of other sections		9 in.
Distance from preceding layer to base of Brassfield bed	66 ft.	

14 R-NE.—About six and a quarter miles south of west from Indian Fields, on the road to Vienna, at the forks of the road about a quarter of a mile south of Log Lick church. (Fig. 2, Plate F.)

Black shale.
Devonian limestone, 67 feet above the base of the Brassfield bed.

16 R-NE.—North of Vienna, along the road from Indian Fields to Vienna.

Devonian not seen at top of the hill.	
Crab Orchard clay shale	38 ft.
Possibly a fault near the base of this part of the section.	
Horizon with large-celled species of *Favosites*, and with *Hindia sphaeroidalis*. The latter was found loose. This is believed to be near the horizon of the 2-foot layer at the base of the Waco horizon of other sections. Distance above the base of the Brassfield bed	85 ft.

If this interpretation is correct, the strata must dip southward at a considerable angle on this hill slope. This requires further study.

17 R-NE.—Eight and a half miles in a direct line west of south of Indian Fields, across the river from Vienna, along the road to the home of Old Jones Finnell. (Fig. 3, Plate F.)

Black shale.		
Hard brown limestone	5 ft.	3 in.
Brecciated clay	1 ft.	
Soft rock	1 ft.	
Devonian limestone with much chert	6 ft.	
Crab Orchard clay shale, not exposed, Estill, Waco and Lulbegrud beds	62 ft.	

Limestone layer.		
Not exposed, probably Oldham clay and limestone....	6 ft.	
Thin, badly weathered limestone interbedded with clay	5 ft.	6 in.
Not exposed, probably chiefly Plum creek clay........	6 ft.	6 in.
Limestone, poorly exposed, with thin clay partings...	3 ft.	6 in.
Strongly cross-bedded layer at top; Brassfield limestone with clay interbedded immediately below; much less clay toward the base..................	9 ft.	6 in.
Massive limestone....................................	4 ft.	2 in.
Top of Ordovician.		
Clay rock, weathering into clay, upper part of Richmond	48 ft.	
Well-bedded argillaceous limestone...................	14 ft.	9 in.
Interval above river, clay rock.......................	17 ft.	6 in.
Base of Richmond, not exposed.		

18 R-E.—Eight and a half miles south of Indian Fields, about three quarters of a mile southeast of Vienna, up a branch entering Rocky creek from the east, along the hillside near the home of James Stone. (Fig. 3, Plate F.)

Black shale.		
Brown, brecciated appearing rock, equivalent to the Duffin layer....................................	5 ft.	
Devonian limestone, with chert......................	6 ft.	
Crab Orchard clay shale with limestone layers at various levels, especially in lower half................	85 ft.	
Massive cross-bedded limestone, probably at the *Whitfieldella* horizon.................................		8 in.
Rotten Brassfield limestone, interbedded with clay at top	3 ft.	
Limestone, badly weathered..........................	2 ft.	
Solid limestone, belonging to the base of the Brassfield bed	8 ft.	
Top of Ordovician, above Red river..................	80 ft.	

L.—Sections Between Rightangle and Merritt.

(Map 5, page 185.)

31 R-NE.—Southwest of Indian Fields five miles, on the road to Merritt, northeast of Arlen, near Goosey's Old Stand.

Brecciated in appearance at top; a little chert in the lower part, 18 inches thick, Devonian limestone...............	5 ft.

The *Whitfieldella* layer occurs near by, but whether brought up by a fault or not, was not determined.

32 R-NE.—About seven miles southwest of Indian Fields, at the fork of the pike about a mile north of Merritt ford, near the old Simpson Brock place.

Limestone, poorly exposed.		
Clayey layer, probably corresponding to the 5-foot Plum creek layer.		
Strongly cross-bedded, sandy layer	1 ft.	
Horizon at top of Brassfield limestone, with large crinoid beads, *Whitfieldella cylindrica-subquadrata*, *Rhinopora frondosa*, *Cyathophyllum calyculum*, *Ptychophyllum ipomea*, and *Dalmanella elegantula* near top. Total thickness of the limestone, including the fossiliferous layers	10 ft.	6 in.

The limestone layers over the five-foot bed are very near the level of the Devonian limestone, possibly brought up by a fault.

33-34 R-NE.—Nearly eight miles in a direct line southwest of Indian Fields, above and below the landing at Merritt's ferry.

Limestone layers.		
Interval, not exposed, probably clay	5 ft.	
Coarse sandy layer, probably the *Whitfieldella* horizon, or just above	1 ft.	
Limestone, Brassfield bed	11 ft.	
Clay rock, weathering readily, upper part of Richmond division	90 ft.	
Tetradium horizon, with *Streptelasma rusticum-canadensis* a short distance above.		
Clayey limestone layers with fossils	10 ft.	
Clay rock, chiefly Richmond	46 ft.	
Indurated clay rock with *Platystrophia lynx Hebertella sinuata*, near top of Maysville division	1 ft.	
Soft clayey shale	6 ft	6 in.
Labechia ohioensis abundant		3 in.
Top of Mount Auburn bed.		
Rubble, clayey limestone with *Platystrophia lynx* and bryozoans very abundant	11 ft.	
Layer with *Hebertella sinuata*, *Platystrophia lynx*, *Lophospira bowdeni*, and bryozoans		6 in.
Layer with numerous lamellibranchs, and with *Orthoceras*	1 ft.	
Argillaceous limestone, rather hard	2 ft.	
Chiefly clayey shale with some clayey limestone, fossils few	15 ft.	6 in.

M.—Sections Between Indian Fields, Clay City, and Lulbegrud Creek.

(Figure 2, plate F, page 184; map 6, page 193.)

7 B-NW.—Southwest of Clay City, about two miles in a direct line, at Tipton ferry.

Irvine clay and sand.		
Black shale.		
Cherty Devonian limestone	2 ft.	
Hard limestone, with cherty nodules, and with fish remains at base	2 ft.	
Soft limestone with fish remains		8 in.
Crab Orchard clay shale, lower part belongs to the fossiliferous Waco horizon	16 ft.	
Brown limestone	1 ft.	4 in.
Horizon with *Favosites gothlandica.*		
Chiefly Lulbegrud clay at top, base of this part of section not seen on account of being below river level	33 ft.	6 in.
Red river.		

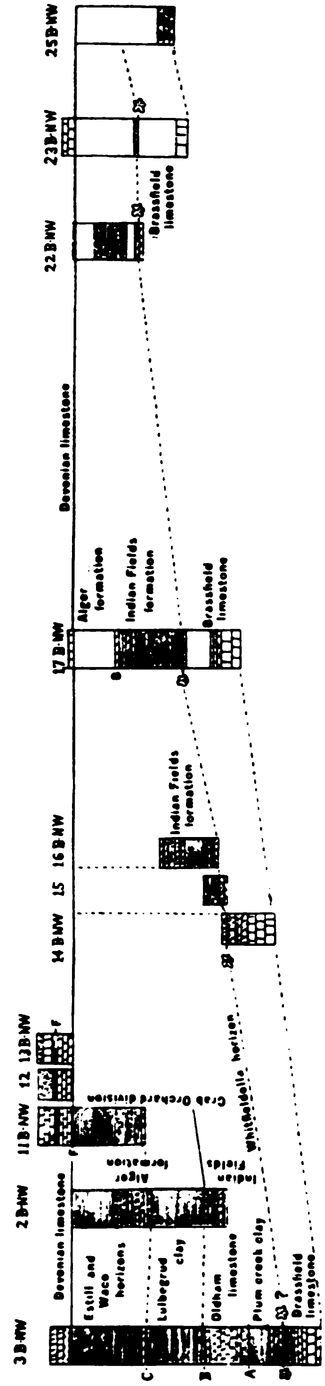
6 B-NW.—West of Clay City, northwest of the bridge across Red river.

Devonian limestone	4 ft.	8 in.

5 B-NW.—About half a mile west of the bridge at the western end of Clay City, along the railroad.

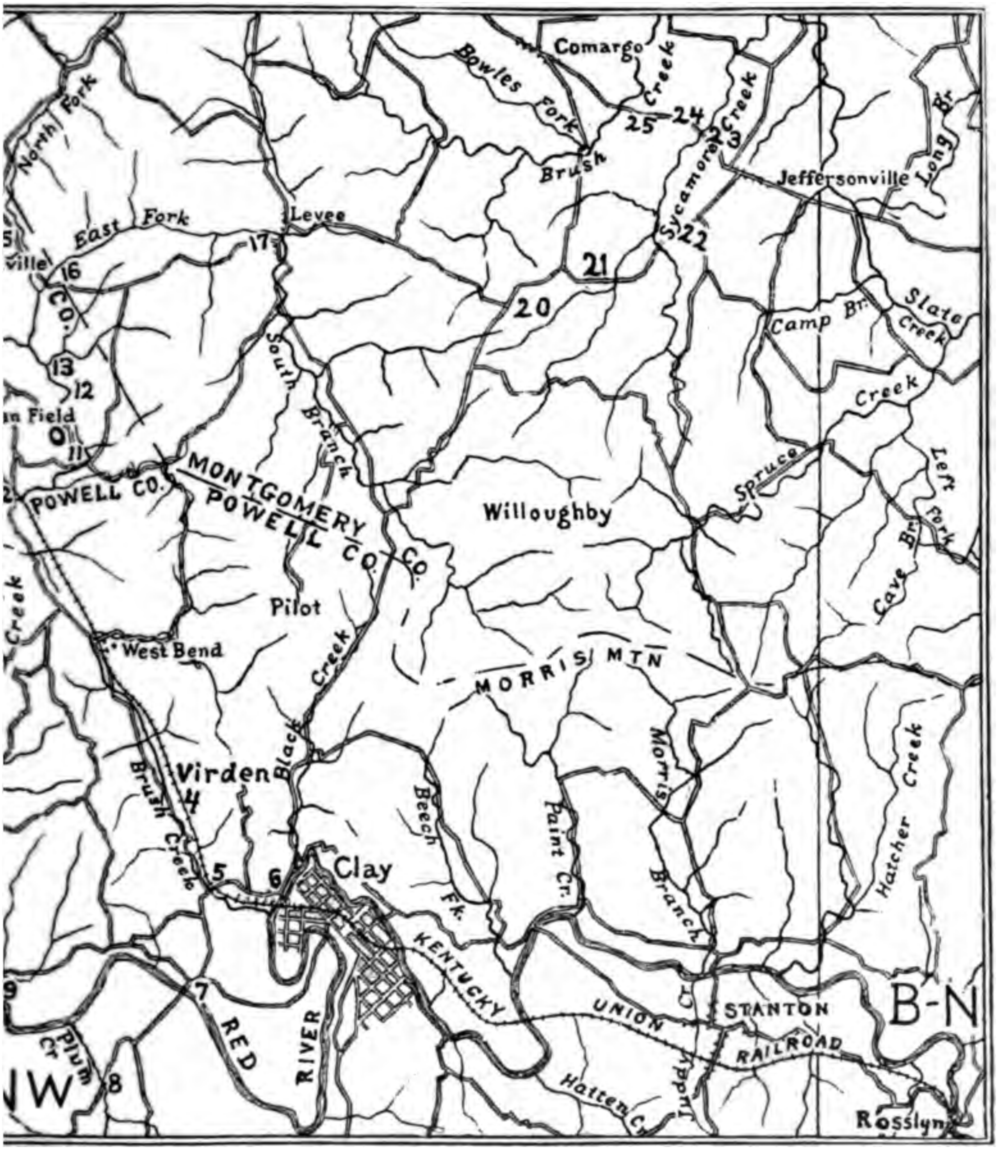
Rusty brown limestone with coarse chert	4 ft.	
Soft rock, weathering back, with Devonian corals in lower part	1 ft.	
Rusty brown limestone with chert, and *Reticularia fimbriata*	1 ft.	8 in.
Rusty brown limestone with small black nodules and fish remains in lower part		6 in.
Waco horizon of the Crab Orchard clay shale, with worm borings, vertical, in a thin clay rock near the top. Within 2 feet of the top occur *Favosites favosus* and *Cyathophyllum.*		

The exposures of the fossiliferous Waco horizon beneath the Devonian limestone continue northwest, toward Virden.



SILURIAN AND DEVONIAN BETWEEN INDIAN FIELDS AND JEFFERSONVILLE.

Plate G. Sections between Indian Fields and Jeffersonville.



Map 6. Map of area between Indian Fields, Clay City and Jeffersonville.

8 B-NW.—Southwest of Clay City, about three miles in a direct line, along the road leading from Tipton ferry to Plum creek, along that part of the road descending toward Plum creek, northeast of the home of George McIntosh.

Irvine formation.		
Black shale.		
Argillaceous rock..................................	1 ft.	8 in.
Devonian limestone, cherty...........................	3 ft.	
Crinoidal limestone with *Hindia*......................	1 ft.	
Soft rock, weathering back...........................		6 in.
Crinoidal limestone..................................		10 in.
Soft rock, weathering back...........................		7 in.
Soft rock with fish teeth, tuberculated plates and black phosphatic nodules........................		6 in.
Estill clay, and Waco clay with limestone layers.....	17 ft.	
Limestone	1 ft.	2 in.
Lulbegrud clay......................................	13 ft.	
Oldham limestone with *Stricklandinia* and *Strophonella* near the top. A ferruginous layer occurs about 6 feet below the top. The lower half contains *Platystrophia daytonensis, Dalmanella elegantula, Leptaena rhomboidalis, Cyathophyllum calyculum*, and *Halysites catenulatus*. Section not clearly exposed, thickness about.................................	11 ft.	
Plum creek clay, exposed in bottom of creek as far south as a point directly east of the home of George McIntosh, formerly occupied by John Burgher....	5 ft.	6 in.
Limestone, strongly wave-marked....................	1 ft.	
Whitfieldella layer.		
Layer with large crinoid beads.		
Brassfield limestone. Owing to the irregular dip of the rock, and the poor exposures, the thickness of the Brassfield bed can not be determined, but it is probably about 19 feet. At this exposure the bottom of the Brassfield bed is found below the nearest Plum creek clay exposure.....................	21 ft.	
Top of Ordovician.		

9 B-NW.—About three and a half miles west of Clay City, north of Hudson's mill, on the road from the mill to Snow creek church.

Black shale.	
Argillaceous rock, brecciated at base as in case of the Duffin layer, with brachiopods....................	9 ft.
Devonian limestone with *Favosites* and *Chonophyllum*.	

10 B-NW.—North of Snow creek church, just before crossing Snow creek.

Devonian limestone.		
Estill and Waco beds of the Crab Orchard Clay shale..	22 ft.	3 in.
Limestone layer.		
Section, upper part chiefly clay (Lulbegrud clay), lower part with limestone layers interbedded (Oldham limestone)	16 ft.	
Plum creek clay bed..................................	5 ft.	6 in.
Whitfieldella layer, ferruginous.		
Limestone, belonging to the Clinton or Brassfield bed.	15 ft.	9 in.
Top of Ordovician.		

N.—Sections West of Indian Fields, Along the Railroad.

(Figure 4, plate F, page 184; map 5, page 185.)

1 R-NE.—Clay pit along the railroad, about three quarters of a mile northwest of Indian Fields.

Irvine formation, sandy clay with pebbles, varies in thickness from 2 to..............................	5 ft.	
Black shale, badly decayed, 1 or 2 feet in thickness at point of observation.		
Devonian limestone, badly decayed..................	1 ft.	6 in.
Estill clay...	7 ft.	
Waco clay with fossiliferous limestones, only the top is exposed.		
Interval, about......................................	38 ft.	
Reddish brown limestone full of *Cyathophyllum calyculum*, probably equivalent to the *Whitfieldella* layer.		
Poor exposures of the Brassfield limestone, along the eastern side of Howard creek.		

2 R-NE.—Northwest of Indian Fields, about a mile, west of Howard creek, along the railroad.

The most eastern exposure of the Oldham limestone contains *Stricklandinia* near the top. Ferruginous layers occur within two feet of the top of the limestone. All the layers of the limestone are well shown at the various cuts along the railroad, but,

owing to the dip, it is not easy to determine the precise thickness of the Oldham limestone at this locality. It is estimated at about fourteen feet. The massive limestone at the base of the Brassfield section is exposed along Howard creek; east of the creek, north of the railroad, it has a thickness of about seven feet.

3 R-NE.—A short distance farther westward, at the western end of a low railroad cut, the following section is exposed:

Light brown or reddish brown limestone with thin clay partings forming lower part of Oldham bed..	8 ft.
Chiefly soft Plum creek clay with a little limestone at the top and with thin streaks of limestone at irregular intervals..............................	5 ft.
Sandy limestone with *Whitfieldella.*	
Strongly wave-marked layer; large crinoid beads near top of underlying layers.	
Reddish brown Brassfield limestone with some interbedded clay, containing *Calymmene rogdesi*, *Cyclonema daytonensis*, *Rhynchotrema scobina*, *Triplecia ortoni*, *Orthothetes fissiplicata*, *Leptaena rhomboidalis*, *Dalmanella elegantula*, *Phylloporina angulata*, *Rhinopora frondosa*, *Phaenopora expansa*, *Zaphrentis daytonensis*, and *Cyathophyllum calyculum*.........	7 ft.
Reddish brown limestone with interbedded clay, and plenty of *Cyathophyllum calyculum* at top..........	5 ft. 6 in.
Reddish brown massive limestone, forming base of Brassfield limestone, about.......................	7 ft.
Top of Ordovician.	

4 to 6 R-NE.—Section from the Hornback curve, a mile and a half west of Indian Fields, westward along the railroad to the home of Tom Will Abbott, three miles west of Indian Fields.

Base of Clinton or Brassfield limesto e at top of the exposure at the Hornback curve. 1.5 miles west of Indian Fields, at locality 4 R-	
Whitish, soft clay, Upper Rich	ft.
Clay, light brown or bl , U r mond	ft.
Clayey rock with s siliferous. U *mena sulcata*, common; Upper *Pterinea*	

Thin bedded clay rock and argillaceous limestone with fossils in the lower part, exact thickness not known, only estimated. Contains *Strophomena planumbona*, common; *Hebertella occidentalis*; *Rhynchotrema capax*; *Streptelasma rusticum-canadensis*; Middle Richmond................................	17 ft.	
More sandy interval, fossils few, Middle Richmond...	17 ft.	
Massive layer of limestone, showing along the foot path from the railroad down northeast to the home of Jim Hornback (locality 5 R-NE); also west of the beginning of this path, at the second cut along the railroad, Middle Richmond..................	1 ft.	6 in.
Massive indurated clay, spalling, well shown in first cut west of path leading down to Jim Hornback. Lower Richmond................................	30 ft.	
Thin bedded clay rock, Lower Richmond............	18 ft.	
Thin shaly section corresponding to the section at the base of the Richmond section along the Kentucky river, east of College Hill, and at Cobb Ferry. Exact age unknown, exposure poor; interval estimated at..	20 ft.	
Platystrophia lynx abundant, associated with *Leptaena rhomboidalis*, at the home of Tom Will Abbott, near top of Maysville division of the Cincinnatian. Locality 6 R-NE..................................	8 ft.	

O.—Sections Between Indian Fields and Jeffersonville.

(Plate G, page 192.)

O-B-NW.—Southeast of the hotel at the Oil spring about a mile and a half east of Indian Fields. From this point the section leads upward along the road toward the Indian Fields and Kiddville pike.

Irvine sands.		
Phosphatic nodule layer at base of Linietta clay.		
Black Devonian shale................................	40 ft.	
Thin clay layers in Black shale at various levels......	15 ft.	
Black (Huron) shale.................................	75 ft.	
Level of the Soda Spring.		
Black shale (Huron), fissile...........................	14 ft.	
More solid layer, earthy, bluish gray, weathering to irregularly shaly fragments......................		3 in.
More shaly, the upper part very fissile and black......	1 ft.	
Solid, light brown, like Duffin layer but not brecciated.		10 in.

Strongly brecciated and weathered so as to bring out the brecciated appearance splendidly, contains celestite, crinoid stems, cyathophylloid and favositoid corals	1 ft.	
Black shale, fissile		2 in.
Solid, light brown limestone, contains black nodules near the base up to ⅝ inch in length. The Oil Spring issues from just beneath this level.		
Estill clay at top of Crab Orchard division of the Silurian.		

O-B-NW.—Northeast of the Oil spring hotel, one hundred yards, in a little run entering Lulbegrud creek from the west.

Black shale.		
Solid limestone		10 in.
Brecciated Duffin layer		10 in.
Solid limestone	1 ft.	2 in.
Limestone weathered cavernous	1 ft.	6 in.
Poorly exposed, solid limestone in part	1 ft.	6 in.
Not exposed, soft		4 in.
Solid, hard, siliceous limestone	1 ft.	3 in.
Rotten stone		1 in.
Ferruginous brown limestone with black nodules		5 in.
Rotten stone		4 in.
Ferruginous brown limestone with phosphatic black nodules		4 in.

13 B-NW.—About a mile east of Indian Fields, at the Hollywood or Stuart mill on Lulbegrud creek.

Black shale.		
Brecciated or Duffin layer	1 ft.	8 in.
Devonian limestone	2 ft.	3 in.
Sandy rock, with tiny black nodules and fish remains.	1 ft.	9 in.
Reddish brown Devonian limestone, with *Phacops rana* and other fossils, massive rock, forming the falls	4 ft.	4 in.
Estill clay division of the Crab Orchard clay shale.		

12 B-NW.—About half a mile southeast of the Hollywood mill, on the eastern side of Lulbegrud creek, at the spring north of the home of Will Lawrence, north of the oil spring.

Black shale, fissile.		
Black shale, with lenticular calcareous layers of rock.	8 ft.	
Brecciated or Duffin layer of limestone	3 ft.	9 in.
Shaly rock	1 ft.	3 in.
Massive Devonian limestone	3 ft.	4 in.
Crumbling rock with fish remains		4 in.

11 B-NW.—East of Indian Fields a mile and a half, south of the Oil spring, at the Eastin mill.

Black shale, interbedded with clayey rock near the base	8 ft.	
Massive Devonian limestone	4 ft.	6 in.
Softer, argillaceous rock	1 ft.	
Massive limestone	3 ft.	6 in.
Layer with fish teeth		1 in.
Estill clay and Waco horizon of the Crab Orchard clay shale, blue	18 ft.	6 in.
Solid limestone		9 in.

14 B-NW.—North of Indian Fields a mile and a half, west of Kiddville, east of the western fork of Lulbegrud creek, north of the road, northwest of Jim Peel.

Along the top of the hillside, loose boulders containing *Whitfieldella cylindrica-subquadrata* and large crinoid beads	1 ft.	
Poorly exposed, Brassfield bed, chiefly limestone but with some interbedded clay at top, and half a foot of clay near the base	5 ft.	6 in.
Limestone, fairly well exposed	7 ft.	6 in.
Top of Ordovician.		

15 B-NW.—Northeast of Kiddville, along a little stream emptying into the northern fork of Lulbegrud creek.

Ferruginous layer.		
Interval not measured, estimated at	3 ft.	
Thin limestone layers with large crinoid beads.		
Heavy cross-bedded layer, full of *Cyathophyllum calyculum;* wave marked at top		8 in.
Remainder of the Brassfield bed not exposed.		

16 B-NW.—Half a mile east of Kiddville, at the junction of the North and East Forks of Lulbegrud creek.

Limestone		4 in.
Thin limestone layers, Oldham bed, interbedded with clay	5 ft.	6 in.
Chiefly blue clay, Plum creek bed, with a little thin limestone, especially toward the top	5 ft.	
Limestone		8 in.
Ferruginous layer with *Orthothetes*	1 ft.	3 in.
Interval	1 ft.	6 in.
Limestone with *Cyathophyllum calyculum* abundant, at top of the Brassfield limestone.		
Remainder of Brassfield bed not exposed.		

17 B-NW.—Northeast of Indian Fields four miles, about a quarter of a mile west of Levee.

Devonian limestone	1 ft.	6 in.
Probably a fault or a strong monoclinal dip.		
Interval	11 ft.	
Light brown, thin-bedded limestones, interbedded with clay, Oldham bed	5 ft.	6 in.
Blue clay, thickness not accurately determined, Plum creek clay, in part. Total interval recorded as	12 ft.	
Sandy limestone with a few large crinoid beads, one with a diameter of one inch, also with *Cyathophyllum calyculum*		4 in.
Very fine-grained purple rock, with large crinoid beads, *Whitfieldella*, *Orthothetes*, and *Leptaena rhomboidalis*		6 in.
Interval belonging to Brassfield horizon not exposed	6 ft.	6 in.
Solid limestone		6 in.
Softer layers, not well exposed	2 ft.	
Massive limestone, unfossiliferous, forming base of Brassfield bed	5 ft.	
Top of Ordovician.		

There is a strong dip here, as much as eighteen feet in a distance of 200 feet. Making allowance for the dip, the distance from the base of the Silurian to the base of the Devonian may be estimated at approximately sixty-seven feet. This would necessitate a considerable increase in the estimate of the strata above the sandy limestone with the large crinoid beads, since no correction for dip was made in taking these measurements.

20 B-NW.—About five and a half miles east of Indian Fields, at the road corner two and a half miles southeast of Levee.

The base of the Waverly, which usually consists of a layer containing phosphatic nodules, consists here of a continuous purple phosphatic bed, varying from one foot to a foot and a half thick.

At the angle in the road, a quarter of a mile farther north, a hard argillaceous rock is found near the base of the Black shale, underlaid by a little additional black shale.

22 B-NW.—About seven and a half miles east of Indian Fields, and a mile southwest of Jeffersonville, where the road crosses Sycamore creek.

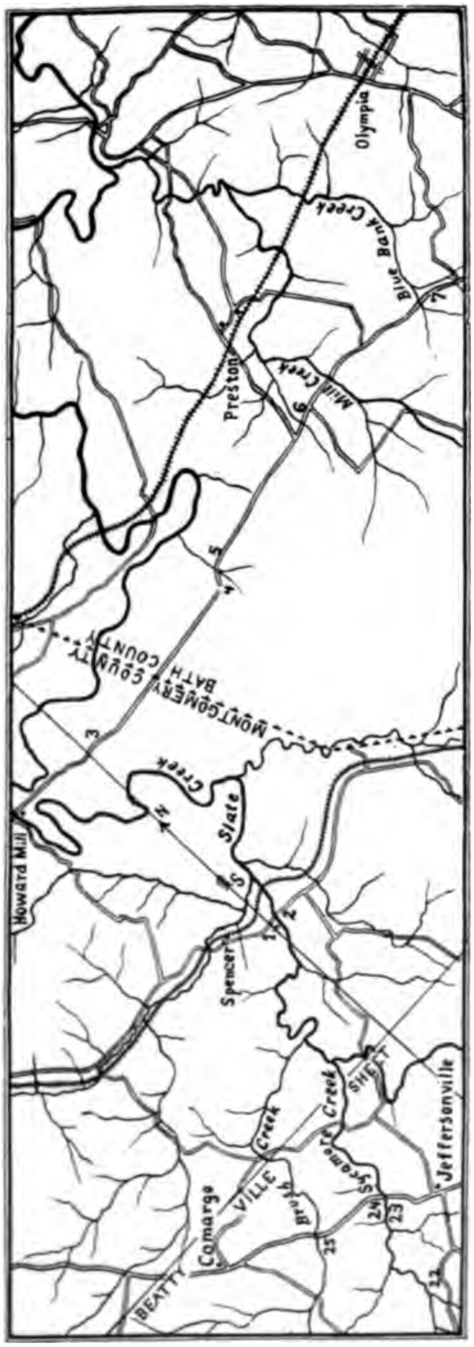
Black shale, fissile.		
Hard argillaceous rock.		
Black shale	5 ft.	6 in.
Hard rock, Devonian		4 in.
Crab Orchard clay shale, including Plum creek, Oldham and Lulbegrud horizons	16 ft.	
Thin, fine-grained purple layer.		
Red sandy rock, with one crinoid bead having a diameter of three-quarters of an inch	1 ft.	6 in.
Limestone in bed of stream, irregularly wave-marked, with lumps of argillaceous rock, also with numerous large crinoid beads, forming top of Brassfield layer.		

23 B-NW.—Half a mile northwest of Jeffersonville, at the crossing of the pike to Mount Sterling over Sycamore creek, east of creek.

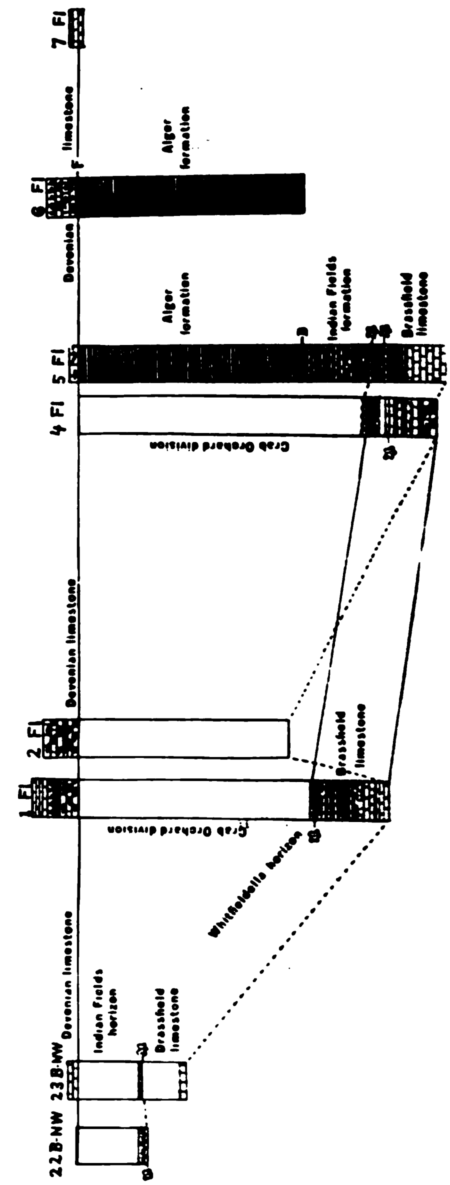
Argillaceous rock in lower part of Black slate section.	
Devonian limestone poorly exposed, on west side of creek	3 ft.
Interval, not exposed, occupied chiefly by Oldham and Plum creek horizons	16 ft.
Red sandy rock	1 ft.
Layer with large crinoid beads.	
Interval occupied by Brassfield limestone	10 ft.
Red massive layer forming base of Brassfield bed	2 ft.
Bed of Creek.	

25 B-NW.—A mile west of Jeffersonville, on the eastern side of Brush creek.

The interval between the base of the Devonian iimestone and the base of the Silurian appears to be about twenty-six feet. The massive layer at the base of the Clinton or Brassfield bed is less than five feet thick, and is cherty. This is the most southern exposure at which the Clinton is found to be distinctly cherty.



Map 7. Map of area between Jeffersonville, Preston and Olympia.



SILURIAN AND DEVONIAN BETWEEN SPENCER AND OLYMPIA

Plate II.

P.—SECTIONS BETWEEN SPENCER AND OLYMPIA.

(Plate H, map 7, page 202.)

1 FI.—East of Spencer, west of Slate creek bridge.

Devonian limestone, brown, not brecciated..........	4 ft. 3 in.	94 ft. 3 in.
Brecciated rock, like Duffin layer....................	1 ft. 6 in.	90 ft
Layer composed almost entirely of chert............	1 ft. 6 in.	88 ft. 6 in.
Devonian limestone with chert and cherty corals....	5 ft.	87 ft.
Interval	61 ft. 8 in.	82 ft.
Limestone full of *Whitfieldella cylindrica-subquadrata*, *Cyathophyllum calyculum*, and *Orthothetes*. It contains thin streaks of fine-grained purple argillaceous rock at top of Brassfield bed............	4 in.	20 ft. 4 in.
Clay	2 in.	20 ft.
Thin, clayey limestone, full of large crinoid beads..	2 in.	19 ft. 10 in.
Chiefly clay...	2 ft. 5 in.	19 ft. 8 in.
Massive limestone....................................	5 in.	17 ft. 3 in.
Clay	6 in.	16 ft. 10 in.
Massive limestone....................................	9 in.	16 ft. 4 in.
Chiefly clay...	10 in.	15 ft. 7 in.
Thin limestone layers................................	10 in.	14 ft. 9 in.
Chiefly clay, poorly exposed.........................	2 ft.	13 ft. 11 in.
Thin-bedded limestone................................	1 ft. 8 in.	11 ft. 11 in.
Massive limestone....................................	8 in.	10 ft. 3 in.
Limestone in thin layers, separated by blue clay partings	3 ft.	9 ft. 7 in.
Massive limestone....................................	1 ft. 4 in.	6 ft. 7 in.
Massive limestone....................................	8 in.	5 ft. 3 in.
Blue clay..	9 in.	4 ft. 7 in.
Thin-bedded limestone. Base of Brassfield bed......	3 ft. 10 in.	3 ft. 10 in.
Top of Ordovician.		

2 FI.—East of Spencer, on the eastern side of Slate creek, south of the pike following the railroad.

Devonian limestone, full of chert......................	5 ft.	65 ft. 2 in.
Interval	1 ft. 2 in.	60 ft. 2 in.
Devonian limestone, massive, cherty..................	3 ft.	59 ft.
Interval	56 ft.	56 ft.
Base of Brassfield bed, exposed on west side of Slate creek bridge.		

3 FI.—Section along the pike east of Howard's Mills.

Cherty base of the Brassfield or Clinton bed.		
Belfast bed		15 in.
Greenish Upper Richmond clay		24 ft.
Sandy clayey limestone interbedded with sandy clay, Middle Richmond	27 ft.	6 in.
Massive sandy Middle Richmond limestone bed, containing *Strophomena vetusta*, *Strophomena planumbona*, *Streptelasma rusticum-canadensis*, and *Hebertella sinuata*	5 ft.	6 in.
Poorly exposed sandy clayey rock, Lower Richmond	12 ft.	6 in.
Blue clay rock, spalling and cracking irregularly	17 ft.	
Sandy clay with *Prasopora* not very common	5 ft.	6 in.
Prasopora hospitalis abundant in sandy clay	6 ft.	6 in.
Hard blue clay rock, regarded as of Lower Richmond age, containing *Prasopora*, *Lophospira bowdeni*, and lamellibranchs	3 ft.	
Bluish clay rock, much broken, Lower Richmond, *Prasopora* common	4 ft.	6 in.
Blue limestone		8 in.
Rubble limestone composed largely of bryozoan remains, probably at junction of Lower Richmond and upper Maysville horizons, including forms of each not carefully discriminated at this exposure.	12 ft.	9 in.
Platystrophia lynx found in lowest part of a section consisting of dark blue clay rock, nearly unfossiliferous, belonging to the Arnheim bed	18 ft.	
Platystrophia lynx abundant at various levels	42 ft.	
Fossils scarce	12 ft.	
Creek level.		

4 FI.—Two and a quarter miles southwest of Preston, west of a small branch entering Slate creek from the south, along the road to Howard's Mills.

Abundant chert, loose, left after the decay of Devonian limestone.		
Interval, poorly exposed, down to base of Plum creek clay	76 ft.	93 ft. 2 in.
Wave-marked layer with large crinoid beads	8 in.	17 ft. 2 in.
Interval	5 ft.	16 ft. 6 in.
Limestone with crinoid beads	2 ft.	11 ft. 6 in.
Solid limestone, belonging to the Brassfield bed	7 in.	9 ft. 6 in.
Irregularly bedded limestone interbedded with clay	3 ft.	8 ft. 11 in.
Blue clay	4 in.	5 ft. 11 in.
Solid limestone	1 ft. 6 in.	5 ft. 7 in.
Blue clay	6 in.	4 ft. 1 in.
Massive limestone with chert, forming the lower part of the Clinton or Brassfield bed	3 ft. 7 in.	3 ft. 7 in.

5 FI.—Southwest of Preston about two miles in a direct line, along the road, east of a small branch entering Slate creek from the south.

Cherty Devonian limestone	2 ft.		96 ft. 10 in.
Alger clay, poorly exposed	60 ft.		94 ft. 10 in.
Thinner Oldham limestone, with more clay	3 ft.		34 ft. 10 in.
Thin Oldham limestone, with less clay	6 ft.	6 in.	31 ft. 10 in.
Plum creek clay	5 ft.	6 in.	25 ft. 4 in.
Wave-marked layer of limestone		4 in.	19 ft. 10 in.
Clay		4 in.	19 ft. 6 in.
Limestone, strongly ferruginous, wave-marked, red purple in part. *Whitfieldella*	1 ft.		19 ft. 2 in.
Brassfield limestone, full of large crinoid beads		2 in.	18 ft. 2 in.
Clay	2 ft.	6 in.	18 ft.
Strongly wave-marked layer of limestone with large crinoid beads		9 in.	15 ft. 6 in.
Clay	2 ft.	3 in.	14 ft. 9 in.
Irregular limestone	1 ft.	2 in.	12 ft. 6 in.
Solid limestone		10 in.	11 ft. 4 in.
Clay		6 in.	10 ft. 6 in.
Massive limestone, belonging to the Brassfield bed	10 ft.		10 ft.

About a mile west of Preston, along the railroad, a short distance east of the home of William Johnson, the *Whitfieldella* layer is exposed. The Devonian limestone is seen farther east, in a deep railroad cut. Here the following exposures are seen:

Devonian Black shale.		
Devonian limestone	11 ft.	8 in.
Alger clay	60 ft.	
Oldham limestone and clay	5 ft.	
Plum creek clay	7 ft.	6 in.
Light brown limestone		4 in.
Clay		8 in.
Ferruginous limestone with large crinoid beads in lower part	1 ft.	
Limestone, containing large crinoid beads and one well-preserved *Whitfieldella subquadrata*		5 in.
Clay, at top of Brassfield section		7 in.
Limestone		4 in.
Clay		7 in.
Ferruginous limestone	1 ft.	
Remainder of Brassfield section not examined.		

About four miles east of Owingsville, on the northern side of Rose Run, there is a wide area in which oolitic iron ore is quarried. Here the following section is exposed:

Oldham limestone and clay, lower part of section....	5 ft.	
Plum creek clay....................................	8 ft.	
Limestone, wave-marked............................		4 in.
Blue hydrated iron ore............................		5 in.
Red hematitic iron ore............................	3 ft.	
Brown limestone, top of Brassfield section...........		5 in.
Clay		4 in.
Limestone with large crinoid beads..................		6 in.
Remainder of Brassfield section not measured.		

6 FI.—South of Preston about a mile, east of a small branch entering Mill creek from the west.

Black shale.		
Brownish rock with traces of the brecciated appearance of the Duffin layer................................	2 ft. 6 in.	68 ft. 3 in.
Cherty Devonian limestone..........................	5 ft. 6 in.	65 ft. 9 in.
Layer with fish remains............................	3 in.	60 ft. 3 in.
Alger clay, exposed for a vertical distance of.........	60 ft.	60 ft.

7 FI.—Southeast of Preston, two miles in a direct line, on the eastern side of Blue Bank creek, south of the road.

Black shale.		
Cherty limestone....................................	1 ft.	
Brown limestone, full of *Ambocoelia umbonata*........	1 ft.	6 in.
Reddish limestone, massive..........................	1 ft.	3 in.

PART II.

ECONOMIC GEOLOGY.

The Silurian and Devonian Clays and Limestones of Eastern Kentucky,

WITH NOTES ON WAVERLY AND IRVINE CLAYS.

CONTENTS OF PART II.

PART II.

ECONOMIC GEOLOGY.

The Chemical Characteristics of the Ordovician Rocks of Kentucky.

The High Bridge formations of Kentucky consist almost entirely of limestone with a high percentage of lime (more than 60 per cent. of calcium carbonate) and a low percentage of silica (less than 5 per cent.). Judging from the few analyses so far recorded, the Camp Nelson and Oregon divisions are distinctly more magnesian (from 10 per cent. of magnesium carbonate in the case of the Camp Nelson division to 36 per cent. in the Oregon) than the Tyrone division (2 per cent.), while the Tyrone division is distinctly more calcareous (95 per cent. of calcium carbonate, in place of 60 per cent., compared with the Oregon, and 80 per cent., compared with the Camp Nelson divisions).

The Curdsville bed, the lowest division of the Lexington formation, consists of crystalline limestone. This is followed by the argillaceous limestones and interbedded clay shales of the Logana bed, and the less argillaceous limestones of the Wilmore division; the Paris bed, which forms the top of the Lexington in by far the greater part of Central Kentucky, again is a crystalline limestone, with a high percentage of lime (often more than 90 per cent. of calcium carbonate). The percentage of silica in the Lexington limestones formerly submitted to analysis is small, and while some of these limestones contained very little magnesium carbonate, others, referred to horizons here called Lexington, are accredited with 10 to 20, and even 35 per cent. of magnesium carbonate. The Perryville limestone, the Upper Birdseye of Linney, has not been studied as yet.

In the lower, or Greendale division of the Cynthiana formation, argillaceous limestones predominate, and these are interbedded with calcareous clays and clay shales, but in the upper, or Point Pleasant division the quantity

of argillaceous material usually is distinctly less, and in some localities the Point Pleasant division contains 80 per cent. of calcium carbonate, and 12 per cent. of magnesium carbonate, with very little silica or alumina. Along the Ohio river, the quantity of silicious material in the limestones at the top of the Cynthiana formation is considerably greater (from 10 to 20 per cent.). The name for the lower of these subdivisions of the Cynthiana formation was suggested by J. M. Nickles; the upper division was named by Professor Orton.

For the lower and middle parts of the Eden division of the Cincinnatian series of rocks the name *Million* beds has been proposed. These consist chiefly of clay shale, limestone forming often less than a tenth, and very frequently less than a fourth of the section. These clay shales are distinctly calcareous (from 5 to 13, and even 18 per cent. of calcium carbonate), the silicious content is considerable (from 50 to 70 per cent.), and the quantity of alumina may equal or even exceed 12 per cent. The quantity of magnesia is usually small, sometimes less than 1 per cent. The limestones of this division usually are rich in calcium carbonate (88 to 96 per cent.) and usually are poor in silica, although occasionally layers with 10 to 16 per cent. of silica occur.

The limestones of the Lower Garrard or Upper Eden bed usually are accredited with a large percentage of silicious material (from 75 to 90 per cent.), with often less than 1 per cent. of carbonate of lime, but with 6 to 10 per cent. of alumina. Specimens not affected by weathering probably would show a greater per cent. of lime. For this part of the Upper Eden bed, the name *Paint Lick* bed is proposed.

The Fairmount bed, in the lower part of the Maysville division of the Cincinnatian series of rocks, contains usually a considerable quantity of rough irregular limestones with an abundance of fossil remains. The percentage of calcium carbonate is high (from 87 to 93 per cent.), while the percentage of silica usually is small (from 1 to 3 per cent.). In the eastern part of the State there is a recurrence of argillaceous, and more silicious limestones in the upper part of the Fairmount bed, reproducing conditions found in the Lower Garrard bed of Central Kentucky. For this phase of the Fairmount bed, the name *Tate* layer is suggested, from the very characteristic exposure about

three miles west of Richmond. An equally good exposure is seen along the railroad, south of Maysville.

The limestones from the upper part of the Maysville division often contain 75 to 88 per cent. of carbonate of lime, and 6 to 14 per cent. of silicious material, with little alumina or magnesium carbonate. The clays, on the contrary, contain from 60 to 80 per cent. of silicious matter, from 7 to 10 per cent. of alumina, and from 3 to 15 per cent. of lime, being very variable as to their calcareous content. To the strata from the base of the Fairmount bed to the middle or top of the Arnheim bed, Prof. N. S. Shaler gave the name Kentucky river limestone.

The Lower Richmond or Waynesville bed, in the greater part of Kentucky, consists of indurated clay rock with a more shaly section at the base. West of the Cincinnati geanticline this is replaced by argillaceous limestone; and towards the Ohio river, on the eastern side of the geanticline, blue clays interbedded with a moderate quantity of thin blue limestones make their appearance.

The Middle Richmond or Versailles bed, in the southern and southeastern part of Kentucky, consists of a considerable quantity of argillaceous limestone interbedded with clay, often more or less indurated. West of the Cincinnati geanticline these limestones often are richly fossiliferous; and toward the Ohio river, on the eastern side of the geanticline, the section not only becomes richly fossiliferous, but the limestones interbedded with the clay are thicker, harder, less argillaceous, and deeper blue in color.

The Upper Richmond or Saluda bed, in all parts of Kentucky, is a distinctly argillaceous formation. Southward, and along the western side of the Cincinnati geanticline, a larger part of this section is strongly indurated and forms an argillaceous limestone. At Madison, Indiana, a sample of this rock, which also would be typical for the exposures in Kentucky as far south as Salt river, gave the following result on analysis:

Silica	19.80
Alumina	15.05
Water (dried at 212° F.)	.35
Water and loss	5.00
Lime	29.19
Magnesia	1.55
Carbonic acid	24.61
Oxide of iron	4.45

This suggests the presence of about 52 per cent. of calcium carbonate, 3.25 per cent. of magnesium carbonate, 5 per cent. of limonite, about 37.45 per cent. of clay, and only 2.35 per cent. of free silica. From this it may be seen that the rock is an argillaceous limestone, and that the term sandstone applied to this rock is incorrect. On the eastern side of the Cincinnati geanticline the upper part of the Saluda bed consists chiefly of soft clay, and northward, toward the Ohio river, clay forms a larger and larger part of the entire Saluda section.

From the upper part of the Richmond division of the Cincinnatian series of rocks, along Muddy creek, near Elliston in Madison county, the following analyses have been published:

2189.—Shelly limestone in the bed of Muddy creek; below the home of J. G. Covington, half a mile below Elliston. Of a dark umber-gray color; generally quite friable; some portions are compact.

Geological position: Richmond group. Collected by John R. Procter and referred by him to the Cumberland shales.

2190.—Impure limestone. From below the mill-dam on Muddy creek, southwest of Elliston. A pretty firm, fine-granular or compact rock of a handsome olive-gray color.

Geological position: From the upper twelve inches of the Richmond division. Collected by John R. Procter, from rocks which he referred to the Cumberland shales.

2191.—Impure limestone. From the same locality as the last. Rather darker colored than the preceding; color inclined to brownish; not so hard as the last.

Geological position: From eighteen to thirty inches below the massive bluff limestone (Brassfield or Clinton bed) of the Silurian on Muddy creek. Collected by John R. Procter from the top of the Richmond division, in rocks identified by him as Cumberland shales.

Analyses; rocks dried at 212 degrees F.:

	No. 2189	No. 2190	No. 2191
Siliceous residue	20.740	25.180	29.080
Alumina		17.656	21.256
Iron peroxide	10.330	3.700	4.120
Phosphoric acid		.204	.204
Water and loss	6.567	4.902	4.302
Lime carbonate	48.530	37.760	33.560
Magnesia carbonate	11.790	10.050	6.955
Potash	1.696	.458	.578
Soda	.347	.090	.045

These analyses suggest that none of the specimens contain more than 5 per cent. of free silica or sand. The rocks are essentially argillaceous limestones with 7 to 12 per cent. of magnesium carbonate, stained by relatively small quantities of limonite.

As far as may be determined from the analyses at hand, the Ordovician strata of Kentucky consist chiefly of calcium carbonate and kaolin. In the limestones, the calcium carbonate, of course, predominates. In some cases it forms more than 95 per cent. of the rock. But in other cases kaolin forms such a considerable proportion of the rock that the name argillaceous limestone is more appropriate. Magnesian limestones appear to be rare or absent in the Cincinnatian, but occur at various horizons in the Jessamine or Mohawkian series of rocks. Limestones containing considerable quantities of free silica or sand are rare apparently, except at the Garrard horizon, and in the lower part of the Maysville division of the Cincinnatian.

In the clays there often is a considerable admixture of free silica or sand (from 20 to 50, and even 60 per cent.), the larger quantities occurring usually in the lower Garrard or *Paint Lick* bed and upper *Fairmount* or *Tate* layer. Magnesium carbonate occurs in small quantities, frequently forming less than 1 per cent., and rarely more than 4 per cent. of the clay. Calcium carbonate also usually forms only a small part of the clay, but it frequently forms as much as 5 per cent., and occasionally exceeds 8, and even 14 per cent. Where it is present in considerable quantities, the clay is likely to be more or less indurated, forming an argillaceous or clay rock.

In collating the various analyses of Ordovician rocks of Ken-

tucky so far published, it was noted that hitherto no systematic investigation of the chemical composition of the Ordovician rocks of the State had been attempted. The selections of samples for analysis appear to have been made at random. Sometimes many analyses have been made from practically the same horizon, while intermediate horizons have remained unknown. Moreover, it is no longer possible to identify with confidence the horizons from which many of the specimens analyzed were obtained; on this account they can not be used safely in forming opinions as to the general characteristics, chemically, of Kentuckian strata. This may be readily accounted for. At the time when most of these analyses were made, the knowledge of the stratigraphy of Ordovician strata was less advanced than at present. In consequence, it was difficult either to identify or to describe horizons from which samples were selected in such a manner that their relative position could be determined with exactness. Under these circumstances there was very little incentive to the systematic selection of material for analysis. Moreover, the demand for artificial cements was less imperative than to-day, and hence one of the possible uses of Ordovician strata did not invite investigation as much as at present.

The same indefiniteness as to horizons is characteristic also of the analyses of the Silurian rocks of Kentucky, hitherto made. A few analyses made in connection with the present survey, however, supplement those by former surveys, so that, while our knowledge of Silurian strata is still very fragmentary, it is, nevertheless, more definite than that of Ordovician rocks. The present paper is to be regarded only as preliminary to fuller investigations and shows merely the present stage of progress.

The preceding account of the chemical characteristics of the Ordovician rocks has been offered only in order to serve as a means of comparison with the Silurian strata, next to be described.

The Chemical Characteristics of the Silurian Rocks of Kentucky East of the Cincinnati Geanticline.

A. Silurian Limestones.

No analyses of the limestones of the Brassfield bed and of the immediately overlying parts of the Crab Orchard bed have been made by the present Survey. A number of analyses, however, have been made by former geological surveys, and, although the exact horizon from which the samples analysed were obtained can not be determined in several cases, in spite of their apparently very definite location, these analyses probably give a very fair idea of the general characteristics of the strata in question.

2192.—Impure limestone; from below the mill-dam on Muddy creek, southwest of Elliston.

Geological position: From the bottom stratum of the Silurian, resting on the top of the Richmond division. This would place it at the base of the Brassfield bed. Collected by John R. Procter.

A granular limestone; somewhat cellular; containing some petroleum, which gives it a brownish color. It weathers ochreous.

2193.—Impure limestone; from below the mill-dam on Muddy creek, southwest of Elliston.

Geological position: Silurian. Top stratum, eight inches thick. Probably from the top of the Brassfield beds, although some of the Oldham limestones of the Crab Orchard bed also are exposed at this locality.

An impure granular limestone; somewhat cellular; dark brownish-gray, somewhat mottled. Contains petroleum, the infiltration of which gave the dark color to the rock. When heated over the alcohol-lamp, the petroleum exudes from it. It weathers ferruginous.

2194.—Impure limestone. From just below the mill-dam on Muddy creek. Elliston.

Geological position: Second stratum from the top. Probably from the upper part of the Brassfield bed. Collected by John R. Procter.

It resembles the preceding, but is darker colored. It also contains petroleum and some iron pyrites.

2195.—Impure limestone. From below the mill-dam on Muddy creek, southwest of Elliston.

Geological position: Third stratum from the top. Probably from the upper part of the Brassfield bed. Collected by John R. Procter.

Resembles the preceding; rather finer-grained and harder; also containing petroleum. Exterior surface weathered ferruginous.

Analyses; samples dried at 212 degrees F.:

	No. 2192	No. 2193	No. 2194	No. 2195
Bitumen, water and loss	1.396	10.870	6.493	2.460
Siliceous residue	9.980	3.980	4.120	3.920
Alumina	11.360	9.960	5.960	12.360
Phosphoric acid				.140
Iron peroxide	3.500	3.900	3.566	4.460
Iron sulphide			.576	
Lime carbonate	45.700	50.860	50.960	51.200
Magnesia carbonate	27.475	20.100	27.972	25.124
Potash	.501	.276	.276	.287
Soda	.088	.054	.087	.049
Total	100.000	100.000	100.000	100.000
Percentage of lime	25.592	28.480	28.538	28.672
Of magnesia	13.083	9.608	13.319	11.899

796, 797.—Clinton Group limestones, from Bath county.

Geological position: Exact position unknown; probably from the Brassfield bed, or the base of the Crab Orchard bed, beneath the Plum Creek clay.

	No. 796	No. 797
Silica and silicates	17.540	1.980
Alumina, iron and manganese oxides	9.020	11.408
Iron carbonate		3.095
Phosphoric acid	.117	.592
Sulphuric acid	.633	.235
Lime carbonate	53.240	51.580
Magnesia carbonate	18.531	28.779
Potash	.444	.209
Soda	.212	Trace

973.—Magnesian limestone. Clinton Group, at Hillsboro, Fleming county. Dull, dirty-buff, impure limestone, with crinoid beads, small specks of mica, and brownish stains of oxide of iron.

Geological position: At very top of the Brassfield or Clinton bed, immediately below the Whitfieldella layer.

674.—Yellow red porous rock, over crinoidal limestone. A mile and a half east of Mount Carmel, Fleming county.

Geological position: Probably the base of the Crab Orchard bed, from the Whitfieldella layer or immediately above.

Analyses:

	No. 973	No. 674
Water and loss	1.858	1.802
Silica and insoluble silicates	10.830	2.880
Alumina	1.080	
Iron oxide	11.073	12.240
Iron carbonate	5.155	
Manganese carbonate	.421	
Phosphoric acid	.848	.630
Sulphuric acid	.324	.337
Lime carbonate	42.680	71.700
Magnesium carbonate	25.358	9.931
Potash	.290	.341
Soda	.033	.139

A comparison of the analyses of the rocks from Muddy creek, near Elliston, in Madison county, shows a considerable uniformity in chemical composition. The rocks are evidently magnesian limestones. The total quantity of calcium and magnesium carbonate varies between 71 and 79 per cent., the quantity of the magnesium carbonate being about half that of the calcium carbonate. The total quantity of alumina and silicious matter varies between 10 and 20 per cent. The silicious matter probably is combined chiefly with alumina, so that there is little free silica or sand. The color of the rocks is due chiefly to iron.

The so-called Clinton limestones, from Bath county, present closely similar features. The total quantity of calcium and magnesium carbonate varies from 72 to 80 per cent., the magnesium carbonate averaging to about half of the calcium carbonate. The color of the rock is due chiefly to iron. The relative quantity of silica and alumina differs considerably in the

two specimens. In sample No. 796 there may have been free silica or sand.

The specimen from Hillsboro, in Fleming county, shows similar features. The total quantity of calcium and magnesium carbonate is 68 per cent., the magnesium carbonate equalling roughly, half of the calcium carbonate. The quantity of iron is considerably greater than in the case of rocks undoubtedly from the Brassfield bed. This agrees with observations so far made in the field, according to which the more distinctly ferruginous layers begin with the layer containing large crinoid beads, at the top of the Brassfield bed, and these are followed by still more ferruginous layers immediately above the Whitfieldella layer, in the lower part of the Crab Orchard bed. The Hillsboro specimen probably contained free silica or sand. This also is in keeping with observations in the field, the crinoid layer at the top of the Brassfield bed, and the immediately overlying layer, usually having a sandy appearance.

The horizon of the limestone from Fleming county is not definitely known. The chief notable features are the much larger percentage of calcium carbonate, and the correspondingly small percentage of magnesium carbonate.

A comparison of the limestones from the Brassfield bed and from the lower part of the Crab Orchard bed with the so-called Clinton limestones of Ohio shows that the latter contain a much larger percentage of calcium carbonate and a much smaller quantity of magnesium carbonate. This appears to be true especially of the more northern or northeastern exposures. For instance, at Centreville and Eaton the percentage of calcium carbonate is about 85, and that of magnesium carbonate about 12; while at Dayton, Brown's quarry west of New Carlisle, and Ludlow Falls the Clinton limestone contains from 91 to nearly 98 per cent. of calcium carbonate, and from 0.22 to 6.5 per cent. of magnesium carbonate. At all of these localities the quantity of silica is very small (1 per cent. or less). The quantity of alumina is even less.

B. The Ferruginous, Phosphatic, and Magnesian Content of Silurian Rocks.

In Kentucky, the most characteristic feature of the Brassfield or Clinton bed, and of the immediately overlying limestones

at the base of the Crab Orchard bed, below the Plum creek horison, is the considerable increase of magnesium carbonate as contrasted with the percentage of this material in the limestones and clays of the Cincinnatian formations. This increase in the quantity of magnesium carbonate is accompanied by a corresponding decrease in the quantity of calcium carbonate.

The increase in the quantity of iron present, although ranging only from 3.5 to 4.5 per cent. when measured in the form of iron peroxide in the case of the Muddy creek limestones, also is noteworthy, since, at many points on the eastern side of the Cincinnati geanticline, this culminates at the base of the Crab Orchard bed in a distinctly ferruginous horizon, which at several localities is of commercial value. Analyses of ferruginous layers from several localities in Bath county show their value as ores.

2575.—Iron ore, from Carnel Rice, taken from the land of Captain W. G. Allen. Ore of a yellowish-brown color of the usual structure (oolitic) of the Clinton iron ore. Bath county.

Geological position: Near the base of the Crab Orchard bed, below the Plum creek horizon. Collected by W. M. Linney, June, 1885.

2576.—Iron ore from the Clinton group on the Purvis lands, in Bath county. Resembles the preceding, but is reddish in color.

Geological position: From near the base of the Crab Orchard bed, below the Plum creek horizon. Collected by W. M. Linney, June, 1885.

2577.—Iron ore. Average sample from the lands of William Warren, near the head of Rose Run. Bath county. Clinton Group. Ore of the structure of Clinton ore, of a reddish-brown color.

Geological position: Near the base of the Crab Orchard bed. Ferruginous layer below the Plum creek horizon. Collected by W. M. Linney, June 1, 1885.

Although the iron in the analysis is estimated as peroxide, some of it, in all these ores, is in the form of ferrous carbonate. These ores have a considerable proportion of lime and magnesia, which will aid in fluxing them, and a notable quantity of phosphoric acid, which will not prevent their profitable use in the production of merchantable iron.

Analyses; samples air-dried:

	No. 2575	No. 2576	No. 2577
Water expelled at 212° F.	1.143	.693	1.607
Carbonic acid, water, etc.	10.863	11.283	8.445
Silica	7.160	7.800	6.960
Alumina	5.468	5.132	3.720
Phosphoric acid (P_2O_5)	1.202	1.138	1.010
Iron peroxide	47.630	51.430	58.570
Lime carbonate	16.560	13.080	15.160
Magnesia carbonate	9.974	9.444	4.528
Percentage of iron	33.341	36.001	40.999

1655.—Limonite with carbonate, said to be eighteen to twenty feet thick, from near Owingsville, on the road to Slate creek.

Geological position: From near the base of the Crab Orchard bed, below the Plum creek horizon. Collected by Philip N. Moore.

Of a fine oolitic structure. Colors varying from yellowish and reddish-brown to grayish-brown, with greenish-gray infiltrations in some parts.

Analyses; dried at 212 degrees F.:

Combined water	7.835	
Siliceous residue	7.350	= 7.560 of silica.
Alumina	8.346	
Iron peroxide	39.063	
Iron carbonate	11.479	=30.734 of iron, total.
Phosphoric acid	.868	= .379 of phosphorus.
Manganese peroxide	not estimated.	
Sulphuric acid	.185	= .074 of sulphur.
Lime, carbonate	18.710	
Magnesia	6.159	

While the percentage of calcium carbonate and magnesium carbonate in these ferruginous layers may seem considerable, viewing them as ores, they are inconsiderable when compared with the quantities of these substances in ordinary Brassfield and lower Crab Orchard limestones. Considered as an ore, the total quantity of silica and alumina also is notable.

The composition and origin of these ores has not been fully investigated. They consist apparently of an intimate mixture

of limonite, hematite and iron carbonate. Where hematite predominates the color is more strongly reddish or reddish-brown. It has been thought by some that the hematite was deposited in place, simultaneously with the calcium carbonate, as part of the original sediment. Water percolating slowly but for long distances through the ground, when coming in contact with rocks having a favorable texture and composition, may take considerable quantities of iron compounds into solution. These iron compounds are taken up probably chiefly in waters containing considerable carbon dioxide and hence are dissolved most frequently in the form of carbonates. If these carbonates enter the sea in areas where the water is comparatively shallow and little affected by currents, rich in vegetation and hence charged with acids derived from decaying plants, they may be precipitated as ferric hydrate or limonite, in accordance with the following reaction:

$$4FeCO_3+3H_2O+2O=2Fe_2O_3.3H_2O+4CO_2.$$

This reaction is materially assisted by a class of bacteria known as iron bacteria, which are unable to exist without the presence of certain chemical substances of which iron carbonate is chief. When the iron carbonate has been taken up by the bacteria, or absorbed by them, it is oxidized and limonite is precipitated. Ordinarily, if the limonite remains where it is kept moist there is no further alteration, but at or near the surface in arid regions or in times of drought in humid regions, it may be dehydrated more or less and thus pass into hematite.

The larger part of the hematite found in sedimentary rocks is due probably to segregation subsequent to deposition. The ore originally was distributed through a much greater mass of rock and subsequently was concentrated in some special layer or layers. Frequently this concentration takes place simultaneously with a replacement of original limestone deposits by the hematite. In these cases the iron compounds, widely distributed throughout the rocks, are dissolved by percolating waters in the form of iron carbonate and transported to other areas. If at any point these waters come in contact with other solutions rich in oxidizing materials, hematite, more or less hydrated, may be precipitated. The reaction is as follows:

$$2FeCO_3+O+water=Fe_2O_3+2CO_2+water.$$

In the case of the ferruginous deposits in the lower part of the Crab Orchard bed, below the Plum creek horizon, on the eastern side of the Cincinnati geanticline, in Kentucky, there is no doubt of a considerable concentration of the hematite and other ferruginous material subsequent to the deposition of the original limestone. At some localities numerous fossil remains occur in the ferruginous material which originally, of course, consisted chiefly of calcium carbonate, but which at present are replaced, as a whole or in part, by hematite or by hematite mixed more or less with limonite and iron carbonate. A microscopical examination of the ferruginous rock reveals, moreover, that a large part of the rock consists of the comminuted fragments of various bryozoans and shells more or less replaced by ferruginous material. While a certain amount of precipitation of ferruginous material may have occurred at the time of deposition of the original sediments, there is no doubt that in their present form these ferruginous deposits are the result chiefly of concentration subsequent to deposition, accompanied by replacement of the original limestone.

All stages of concentration, between limestones slightly tinged with limonite, hematite, or iron carbonate and those in which the limestones have been replaced by sufficient of these materials to constitute ores, may be observed usually at the same locality. The ferrous carbonate in the rock is due to replacement of calcium carbonate and not to original deposition.

The notable quantity of phosphoric acid recorded in the chemical analyses of these ferruginous rocks also is due to concentration subsequent to the deposition of the original limestones. This quantity is not large, but it is larger than in the non-ferruginous layers. The phosphates, as a rule, are dissolved by percolating waters near the surface where the rocks are weathering and are segregated at or just below the level of the ground water. This segregation occurs most frequently in limestones. It has been suggested that this precipitation is brought about simply by the interchange of the bases in the phosphates and carbonate of lime thus brought together. It may have resulted also from the lowering of the solvent power of the percolating water due to loss of carbon dioxide. This would take place whenever a part of the carbon dioxide was used up in dissolving limestone or when a part of the carbon

dioxide escaped from the ground waters due to relief of pressure on approaching the surface of the ground. The zone of the deposition of phosphates frequently is also the zone of the removal of calcium carbonate. It is closely associated with the zone of weathering. This raises the question whether the beginning of the period of deposition of the Crab Orchard bed may not have been a period of weathering of rocks in this and in closely contiguous areas. The sudden introduction of *Whitfieldella subquadrata* at and immediately above the horizon with large crinoid beads, at the very base of the Crab Orchard bed suggests some important change geographically. At this horizon the rock often is distinctly sandy. The tops of the limestone layers frequently are strongly wave-marked. Shallow water conditions, at least, appear to have prevailed.

Finally, the magnesian content of the Silurian limestones deserves some consideration. The quantity of magnesium carbonate in the specimens analyzed is not sufficient, in conjunction with the calcium carbonate, to form anything like a dolomite. Nevertheless, magnesium carbonate is an important constituent of the rock. The source of this magnesium is not organic. In the shells and skeletons of marine animals the quantity of magnesium carbonate usually is less than 1 per cent. Magnesium carbonate is present in sea water. It is present in larger quantities than calcium carbonate, but the calcium carbonate is largely taken up by sea animals in the construction of their shells and other hard parts, while but little magnesium carbonate is used in this manner. Under ordinary conditions magnesium carbonate precipitates much less readily than calcium carbonate, and is thrown down from solution later than the latter. It is not known to occur as a chemical precipitate in sea water, which is far from being saturated with this substance. Magnesium carbonate, in consequence, does not appear as an important original constituent of rocks. Hence the appearance of any considerable quantity of magnesium carbonate in rocks suggests the presence of the incipient stages of dolomitization, or of the partial replacement of the calcium carbonate of limestones by magnesium carbonate. This magnesium carbonate is supposed to be derived from the various magnesium containing minerals of the older rocks, or from the more or less dolomitic limestones of later age. In the more concentrated

areas, cut off from the general circulation of the sea, dolomitization may take place contemporaneously with the deposition of limestones, but as a rule dolomitization is believed to have taken place chiefly after the elevation of limestone deposits above the level of the sea, when the circulation of percolating waters throughout its mass is certain to be greater.

It has been noticed that magnesian limestones are more abundant among the older rocks of the earth. It may be that in these cases dolomitization has had a longer time to be operative. It has been noticed also that magnesian limestones are more abundant in faulted areas, where circulating waters had better opportunities to bring the magnesium carbonate into solution. In the case of the Silurian limestones of Kentucky no investigations were made as to the origin of the magnesian content.

Nothing is known of the chemical composition of the Oldham limestones in the lower part of the Crab Orchard bed beyond the few notes on the moderately ferruginous layers given in the earlier half of this bulletin. Several analyses have been made, however, by the present Survey, which give a fair idea of the general characteristics of the extensive layers of clay which form the major part of the Crab Orchard bed.

C. Silurian Clays.

1. Analyses.

Most of the following analyses have been made for the present Survey, but several are appended which were made for the earlier surveys; as far as is possible from the information at hand, the geological positions of the samples collected by the latter are indicated in accordance with the revised classification.

2598.—Clay. From Panola, along Oldham branch, southeast of the railroad station; Madison county.

Geological position: Plum creek clay. A five foot clay layer at the base of the Crab Orchard bed, immediately above the Brassfield or Clinton limestones. Collected by A. F. Foerste, 1904.

bed is six or more feet thick, and contains gypsum. Locality: R-S-21. Probably belongs to the Lulbegrud clay division of the Crab Orchard bed.

Generally in thin, soft, irregular laminae, of a light olive-gray color, irregularly varied with brownish yellow or ochreous. It contains gypsum in irregular crystals between some of the laminae. It is quite plastic with water. Burns quite hard, to a handsome light brick color.

Analysis, dried at 212 degrees F.:

Combined water, carbonic acid, and loss	5.871
Silica	48.780
Alumina	17.320
Iron peroxide	3.240
Lime sulphate	19.285
Magnesia	.496
Potash	4.768
Soda	.240

2170.—Indurated clay. From the farm of C. L. Searcy, near Elliston, west of Waco one mile; Madison county.

Geological position: Collected by John R. Procter and stated by him to occur beneath the Corniferous limestone and to form a bed ten or more feet thick, and to make good soil. At Waco the base of the great mass of clays forming the upper clay of the Crab Orchard bed occurs below the Devonian limestone. It may be that the base of this upper (Estill) clay is present also on the Searcy farm, although this clay is known to thin out eastward.

Analysis, sample dried at 212 degrees F.:

Combined water and loss	4.147
Silica	62.580
Alumina	22.940
Iron peroxide	3.760
Lime	.560
Magnesia	.425
Potash	5.280
Soda	.308

2599.—Clay. From Panola, at the railroad cut east of the station.

Geological position: From the upper clay of the Crab Orchard bed, forming the main body of clays (Estill) above the Waco horizon. Collected by A. F. Foerste, 1904.

Analysis, air-dried:

Moisture	2.20
Ignition (combined water, etc.)	7.80
Silica	54.33
Alumina	19.44
Ferric oxide	5.00
Lime	1.88
Magnesia	2.22
Potash	5.15
Soda	.31
Titanium dioxide	1.13
Sulphur trioxide	.39
Total	99.85

2601.—Clay. From Irvine, on the hillside northwest of the home of James F. Harris, one mile north of town; Estill county.

Geological position: The upper or chief body of clay (Estill) in the Crab Orchard bed, overlying the Waco horizon. The specimens analyzed were a mixture of clays collected between twenty-seven and fifty-seven feet above the two-foot layer of limestone which forms the base of the Waco horizon. Collected by A. F. Foerste, 1904.

Analysis, sample air-dried:

Moisture	2.13
Ignition (combined water, carbon dioxide, etc.)	7.26
Silica	55.25
Alumina	20.79
Ferric oxide	4.40
Lime	1.51
Magnesia	1.04
Potash	4.95
Soda	.41
Titanium dioxide	1.16
Sulphates	Trace
Total	98.90

2619.—Crab Orchard. At the exposure south of the roadside well at the north end of the grounds belonging to the Crab Orchard Springs hotel, one mile north of the station, and a quarter of a mile south of Dix river.

Geological position: From the upper or chief clay (Estill) layer forming the greater part of the Crab Orchard bed. Col-

lected from the upper part of the section, fifty-five feet thick. These clays belong above the Waco horizon. Collected by A. F. Foerste, 1904.

Analysis, sample air-dried:

Moisture	1.69
Ignition (combined water, carbon dioxide, etc.)	7.86
Silica	54.48
Alumina	18.90
Ferric oxide	5.64
Lime	2.50
Magnesia	1.71
Potash	4.67
Soda, traces lithia	.38
Titanium dioxide	1.12
Sulphates and phosphates	Traces
Total	98.95

2186.—Clay shale. On the road near Anderson Lake's house, three hundred yards west of Drowning creek, two miles southwest of Panola, a mile and a half northwest of Combs.

Geological position: Collected by John R. Procter, from the "Niagara Group." Either from the Lulbegrud clay division of the Crab Orchard bed, or from the upper clay (Estill) of this bed, above the Waco limestones; probably the latter. Locality, R-SE-21.

An olive-gray and brownish gray, somewhat firm shale, mottled in parts. Quite plastic with water when powdered. Calcines to a light brick color.

Analysis, dried at 212 degrees F.:

Combined water, carbonic acid, and loss	16.221
Silica	42.300
Alumina	20.840
Iron peroxide	4.120
Lime	13.320
Magnesia	.461
Potash	2.387
Soda	.351
Total	100.000

2. Possible Uses of Silurian Clays for the Manufacture of Clay Products.

If attention be confined to the clays investigated by the writer, a considerable similarity in the chemical composition of the clays from the different horizons is noticed. The percentage of silica in these samples varies from 50 to 58 per cent; that of alumina, between 18 and 21 per cent.; that of ferric oxide, between 4.5 to 5.5 per cent.; that of potash, between 4.6 and 5.3 per cent.; that of soda, between 0.3 and 0.4 per cent. The percentage of lime and magnesia, however, is much more variable, the proportion of these substances being greatest in the case of the sample of Plum creek clay.

These samples of clay were selected with special reference to their availability for commercial purposes. Considerable care was taken to secure samples from localities where large quantities of these clays were available and to select the material in such a manner that an analysis of the mixture would give a very fair idea of the general characteristics of the clay as they would appear under ordinary methods of manipulation.

From these preceding analyses it is evident, of course, that they have no value as fire-clays. They contain too much of each one of the fluxing materials: potash and soda, ferric oxide, and lime, and magnesia. On this account they melt at too low a temperature and hence will not serve for brick intended to stand a high temperature.

They also have no value as stoneware clays, as the following table, giving the range of the percentage of the various constituents of good typical stoneware clays, will show:

	Maximum	Minimum	Average of eight analyses
Silica	72.10	45.00	64.08
Alumina	38.24	19.68	23.86
Ferric oxide	1.50	0.96	1.23
Lime	1.70	0.00	0.78
Magnesia	0.68	0.11	0.40
Soda	Trace	0.00	Trace
Potash	2.42	0.15	1.48
Oxide of lithium, with some soda	0.02	Trace	Trace
Titanium oxide	1.30	0.29	0.46
Water	14.80	6.25	7.78

A comparison of the analyses of the Silurian clays with this table indicates that the Silurian clays contain too great a percentage of fluxes. In place of a maximum of 2.4 per cent. of alkalies, as in good stoneware clays, the Silurian clays contain from 5 to 5.6 per cent. of potash and soda. In place of a maximum of 3.9 for the total quantity of ferric oxide, lime and magnesia, the Silurian clays contain between 7 and 13 per cent.

As far as may be determined from the analyses, these Silurian clays should be almost ideal for the average run of vitrified wares. This is well brought out by the following table, which indicates the range of variation of the principal constituents in a number of clays which have been found to be of value for these purposes.

	Maximum	Minimum	Average
Silica	75.00	49.00	56.00
Alumina	25.00	11.00	20.50
Ferric oxide	9.00	2.00	6.70
Lime	3.50	0.20	1.20
Magnesia	3.00	0.10	1.40
Soda and potash	5.50	1.00	3.70
Loss on ignition	13.00	3.00	7.00

In the Silurian clays here discussed, the percentage of silica varies between 54 and 59 per cent., except in the case of the Plum creek clay, where the proportion of silica is nearly at a minimum. The percentage of alumina varies between 18 and 21; that of ferric oxide between 4.5 and 5.5 per cent. The percentage of lime exceeds the maximum in the case of the Plum creek clay, but varies between 0.9 and 2.5 per cent. in the other cases. The magnesium also is in excess in the case of the Plum creek clay. The alkalies, potash and soda, on the contrary, are fairly high in the case of all of the clays (from 5 to 5.6 per cent.).

Clays of this description are used for sewer pipe, paving brick and other purposes, where the materials do not have to withstand high temperature. Clays of this class should be fine-grained and plastic, and should vitrify at temperatures as low as 2,130 to 2,210 degrees F. On this account the clays should contain a considerable amount of fluxing materials. However, to prevent complete fusion, there should not be much potash

and soda, since in these cases there is frequently too little difference in temperature between the point of incipient fusion and that of complete fusion. The difference between these points should be about 150 to 200 degrees F., in order that the articles made from the clay may be raised to the temperature of incipient fusion or vitrification without any danger of the temperature rising sufficiently to approach complete fusion, which, of course, would cause the articles formed from the clay to lose their shape, stick together, and become altogether useless.

High-grade terra cotta work is now made from a mixture of fire-clays which burn to a buff color. The Silurian clays here under discussion are not fire-clays, and they would not burn to a buff color. Clays containing 5 per cent. or more of iron burn to a deep cherry-red, unless under-burned, in which case the resulting ware loses in strength, and in fact may be worthless. There is no known reason, however, why the Silurian clays in question should not prove available for the lower grades of terra cotta.

On account of their large percentage of iron, these Silurian clays are not available for the manufacture of yellow and buff brick. They should, however, make excellent bricks of the common red variety. Brick clays should have a sufficient percentage of fluxes to reach incipient fusion at a little over 1,900 degrees F., and should burn hard at a temperature not over 2,000 degrees F. The Silurian clays here discussed have not been tested as yet as to their fusibility. It is probable that a good quality of pressed brick might be made out of these clays, but the color would be deep red and the brick would not be as hard as the pressed bricks made of more refractory material.

The clay from the C. L. Searcy farm shows a distinctly higher percentage of silica, and a distinctly smaller per cent. of lime, magnesia and iron than the clays collected by the writer. The clays from the Dr. Freeman and Anderson Lake localities are notable chiefly for the large quantities of calcium which they contain. In the case of the clay from the Dr. Freeman locality, the calcium is determined in the form of calcium sulphate, indicating the presence of considerable quantities of gypsum.

The use of the Crab Orchard clays for the purpose of manufacturing artificial cements should receive further attention. At present many of these artificial cements enter the market

under the name of Portland cements. Various materials may be used in the manufacture of these cements. Among these are marl mixed with clay, limestone mixed with clay, argillaceous limestone mixed with pure limestone, limestone mixed with shale, limestone mixed with slag from iron furnaces, and clay mixed with the calcareous waste left from the manufacture of caustic soda.

In order to give some idea of the sort of mixtures of limestone and clay that have proved to be of practical utility in the manufacture of Portland cements, the following analyses have been added. The first column in each table gives the ingredients of the limestone entering into the mixture, the second column gives the ingredients in the clay used, and the third gives the composition of the finished product, the so-called Portland cement.

Analyses of materials used by the Catskill Cement Company, at Smith's Landing, in Greene county, New York, and published by the New York Survey:

	Limestone	Clay	Resulting cement
Silica	1.54	61.92	22.48
Alumina	.39	16.58	6.52
Ferric cxide	1.04	7.84	4.46
Lime	53.87	2.01	62.93
Magnesia	.52	1.58	1.48
Alkalis		3.64	
Sulphur trioxide		Trace	1.30

The following analyses were published from an investigation of materials used by the Glen Falls Portland Cement Company, in Warren County, New York:

	Limestono	Clay	Resulting Cement
Silica	3.30	55.27	21.50
Alumina, ferric oxide	1.30	28.15	10.50
Lime	52.15	5.84	63.50
Magnesia	1.58	2.25	1.80
Alkalis			.40
Sulphur trioxide	.30	.12	1.60
Carbon dicxide	40.98		
Organic matter and water	8.37		

In the latter case the limestone and clay are dried and crushed separately. After being weighed on automatic scales, the materials are mixed dry and reduced to fine powder. This powder is then fed into wet mixers, where sufficient water is added to allow the mixture to be made up into bricks. The bricks are dried in tunnels heated by waste heat from the boiler, blowers being used to drive the heat through the tunnels. After drying, the bricks are burned in kilns, and the clinkers resulting from the brick are reduced to powder in mills constructed for this purpose. The powder is the finished product, the Portland cement.

The essentials in the manufacture of Portland cements are lime and silica. The lime is furnished by limestone or marls, and the silica is furnished by the clay. In burning, the lime and silica unite so as to form the compound $3CaO.SiO_2$, called tricalcic silicate. This compound, in large measure, supplies the hydraulic properties of the cements. The ideal Portland cement would consist, therefore, exclusively of tricalcic silicate, and would be composed entirely of lime and silica in the proportion of 73.6 per cent. of lime and 26.4 per cent. of silica.

Such an ideal cement, however, can not be prepared at present under conditions such as to make it a commercial product, since the heat required to cause pure lime and silica to unite can not be attained in any commercially useful kiln. In actual practice, therefore, it becomes necessary to select materials which, in addition to lime and silica, contain also other ingredients which will serve as a flux. The most important of these ingredients are alumina and ferric oxide, and when present in notable percentages they lower the temperature at which lime and silica will combine to a considerable degree. However, as the percentage of alumina and ferric oxide increases, the strength of the Portland cement decreases, so that considerable judgment must be used in the selection of materials.

In burning, the alumina is believed to combine with the lime so as to form dicalcic aluminate, $2CaO.SiO_2$, and there is a possibility of a similar combination in the case of ferric oxide, forming the compound $2CaO.Fe_2O_3$. Owing to the relatively small percentage of ferric oxide in the materials used for Portland cements, it may be considered as producing about the same effect as alumina, and the two may be calculated together.

Owing to the necessity of having the fluxing materials, alumina and ferric oxide, present, in addition to the lime and silica, the necessary elements of Portland cement, before burning, may be said to be about 75 per cent. of carbonate of lime, and 20 per cent. of silica, alumina, and iron taken together. The remaining 5 per cent. will include the magnesium carbonate, alkalies, and sulphur compounds which may be present. Of the essential ingredients, the lime is usually furnished by the limestone, while the silica, alumina, and ferric oxide are supplied by the clay.

Some of the impurities found in the unburned materials may be regarded as useful to the cement. One of these is calcium sulphate, which, if present only in small quantities, retards the set of the cement. Magnesium carbonate is an undesirable impurity in the unburned mixture, and should form less than 3.5 per cent. of the latter.

For use as Portland cements the clays should carry not less than 55 per cent. of silica, and preferably from 60 to 70 per cent. The alumina and ferric oxide calculated together should not amount to more than one-half of the percentage of the silica. The value of the clay is greater in proportion as the ratio of its ingredients approaches $Al_2O_3+Fe_2O_3=\frac{SiO_2}{3}$. The percentage of magnesia and alkalies should be low, preferably not over 3 per cent.

From these statements it is seen that there is a possibility of the usefulness of the Crab Orchard clays for Portland cement, but that its usefulness can not be determined definitely until the composition of the available limestones is known, and the latter has not yet been determined.

3. THE MINERAL WATERS AND SALTS OF THE CRAB ORCHARD BED.

Crystals of gypsum are common at certain horizons in the Crab Orchard bed. They are abundant in the Lulbegrud clay layer along the railroad southeast of Brassfield; also in the lower part of the upper or Estill clay of the Crab Orchard bed, above the Waco horizon, at Panola, north of Irvine, and at various other localities. The crystals occur in several forms. In a large number of cases the crystals are elongated parallel to

the clino-axis, producing long negative pyramid and clinopinacoid faces and short unit prism faces, which give the crystals a sort of prismatic aspect. In another common form the crystals have a sort of elongate tabular appearance. In this case the crystals show twinning, the orthopinacoid being the twinning plane. The broad, flat faces are formed by the two clinopinacoids, while the two narrow faces on either side are formed by the unit prism faces. At one end there are four pyramid faces consisting of the two pairs of negative unit pyramid faces belonging to the twins. At the other end there is a corresponding re-entrant angle.

In a third group of crystals the gypsum assumes the familiar swallow-tail form of twins. In this case the orthopinacoid again is the twinning plane, but the greater part of the growth of the crystal is lateral, especially parallel to the clino-axis, rather than in the direction of the vertical axis. On the upper side of the twin the negative pyramid faces are well developed; on the other side the orthodome faces, *e*, round off apparently into the lower pyramid faces and thus form the peculiar re-entrant angle which gives rise to the swallow-tail form. Sometimes this twinning takes place alternately first towards the right and then toward the left, producing a sort of arborescent or pagoda-like cluster. In these cases the elements of the cluster often have a more lenticular form.

Gypsum, or hydrous calcium sulphate, is not the only sulphate found in the Crab Orchard clays. As a rule, however, the other sulphates do not occur in sufficient quantities to show in an ordinary analysis of the clays. In an analysis of the waters obtained from the clays, on the contrary, some of these sulphates are readily detected, their ready solubilities causing them to form a much larger proportion of the solids dissolved in the water than of the solids forming the mixture of substances called clay. Among these sulphates is hydrous magnesium sulphate, also called epsomite or Epsom salt. This is a common substance in mineral waters. In the solid form it often occurs in mines and caves as delicate fibrous coatings on the walls or as minute crystals mingled with the earth on the floors of these underground passages. In Mammoth Cave it adheres to the roof of the cavern in loose masses like snow balls. It is very soluble in water. At 32° F. one hundred parts

of water dissolve 25.76 parts of anhydrous sulphate and .265 parts for every additional degree rise in temperature. It has a rather disagreeable taste and is at the same time salty and bitter. It possesses purgative properties and occurs in the mineral waters of wells such as those of Epsom, in England, and Sedlitz, in Bohemia.

Another common ingredient of the waters obtained from the Crab Orchard clays is hydrous sodium sulphate or Glauber salt. This also is very soluble in water. One hundred parts of water at 32° F. will dissolve 12 parts of sodium sulphate, and at about 65° F. will dissolve about twice this quantity. The solution has a rather disagreeable, salty and bitter taste. It is well known as a purgative.

Potassium sulphate is much less soluble in water, only 11.5 parts being taken up by 100 parts of water at 65° F. It occurs in the waters of the Crab Orchard clays only in small quantities. Sodium chloride also occurs only in small quantities, especially when its ready solubility is considered, one part of salt dissolving in about 2.7 parts of water at almost any ordinary temperature.

The springs issuing from the Crab Orchard clays sometimes contain a sufficient quantity of salts in solution to be known as *licks*. This name dates back to the early history of the State of Kentucky, when herds of buffalo and deer still roamed through Kentucky forests and visited these springs in large numbers. A large number of the smaller streams originating among the Crab Orchard clays are still known as *licks*, the name often having been used not only for the springs but also for the streams fed by the springs. The quantity of mineral matter carried in solution varied, of course, in different springs. Among the springs or wells carrying the greatest quantity of magnesium sulphate and sodium sulphate in solution may be mentioned the Epsom well about a mile north of Crab Orchard Springs, on the western side of the Lancaster pike; the Foley well about half a mile northeast of Crab Orchard, on the Fall Lick road, two or three hundred yards beyond the cemetery; and the Sowder well, half a mile northwest of the Epsom well, along the road leaving the Lancaster pike a short distance south of the Dix river bridge. Analyses of the waters from these wells are given below.

Number of analysis / Name of well	535 Epsom	536 Foley	538 Sowder
Silica	.060	.056	.021
Iron carbonate	Trace	Trace	Trace
Lime carbonate	.673	.912	.506
Magnesia carbonate	.116	,131	.375
Lime sulphate	.203	.185	1.566
Magnesia sulphate	3.454	3.520	2.989
Potash sulphate	.067	.170	.298
Soda sulphate	.774	1.013	.398
Sodium chloride	.081	.304	1.000

The medicinal virtues of the waters issuing from the springs or licks soon became recognized. At an early date the waters were evaporated and the ingredients, in a solid state, were sold under the name of *salts*, these from Crab Orchard enjoying a special celebrity. Their first manufacture dates from 1826, when a Mr. Reuben Dollins lixiviated the earth derived from the Crab Orchard clays, and boiled the solution obtained until the salts were thrown down. These were kept at the bar at the old Davenport hotel, in Crab Orchard, and sold at twelve and one-half cents a dose. Dollins afterwards boiled down the water from a spring. The manufacture of these salts, in the course of time, became a profitable business. It was carried on at all seasons of the year and gave employment to a number of families, who obtained their entire living from this industry. The salts became an article of trade and were used as medicine all over the country, especially in the Mississippi valley. It is interesting in this connection to note that at one time they had quite a reputation in the treatment of yellow fever, a groping in the dark for a remedy for this terrible scourge.

At a later time more concentrated solutions of these salts were obtained by digging pits into the clay. These were usually three to four feet wide, six to twelve feet long, and six to twelve feet deep. Generally the walls were planked up and the wells were covered in order to prevent the dilution of the water seeping into the wells by entering rain. Water seeping through the clay became impregnated with the salty materials in the shales, but on entering the pits were exposed to evaporation which resulted in a considerable concentration of the water in the well or pit before it was subjected to boiling. The water

was evaporated in large iron kettles or pans over wood fires. When the large part of the water had been removed, the final stages of evaporation were completed in smaller kettles over slower fire. The residue appeared very much like a mixture of coarse brown and white sugar. In the best brands, the salts were ground so as to give them a better appearance. From twenty to fifty gallons of water were required to make one pound of salt. These salts in the earlier stages of this industry brought as much as one dollar a pound, but at the time when Linney wrote his report on Lincoln county, in 1882, they sold for only fifteen cents per pound.

The following are analyses of two samples of salts as they were offered for sale by druggists in Louisville in earlier days, when this was still a thriving business.

1874. Crab Orchard Springs salts. Evaporated from the water secured at various springs.

1875. Crab Orchard Springs salts. Evaporated from water secured from various springs.

Analysis. Dried at 212° F.:

	No. 1874	No. 1875
Water of crystallization and loss	23.421	24.402
Silica	.124	.118
Iron peroxide	.078	.028
Lime carbonate	.032	.018
Magnesia carbonate	.089	.036
Lime sulphate	2.149	1.795
Magnesia sulphate	54.842	60.627
Potash sulphate	2.707	2.814
Soda sulphate	13.566	8.260
Sodium chloride	2.954	1.874
Lithia sulphate	.038	.028

The area from which these Crab Orchard salts were obtained centered chiefly about Crab Orchard. Wells were operated as far west as Cedar creek, as far north as the Dix river, and up the Dix river valley, east of Crab Orchard, as far as the Crab Orchard clay bed was exposed. In all of these cases, as far as known, these wells or pits were opened in the great series of clays forming the upper part of the Crab Orchard bed, above the Waco horizon.

Similar mineral waters, however, occur also in the Lulbegrud layer, for instance at Kiddville, in Clark county. An analysis of the water of the Epsom well at Kiddville is here appended. It was an ordinary walled well at first, but afterward was enlarged so as to produce a pit 10 feet in diameter. For some reason this spoiled the well and operations were discontinued.

2471.—Magnesium mineral water. From a well at Kiddville, on the property of J. E. Groves. Collected by W. M. Linney, July, 1884.

Analysis. In 1000 parts of water.

Iron and manganese carbonates	.0024
Lime carbonate	.3740
Magnesia carbonate	.0191
Lime sulphate	3.2610
Magnesia sulphate	4.7776
Potash sulphate	.0490
Soda sulphate	.7118
Sodium chloride	.2120
Lithium chloride	.0130
Silica	.0100
Total saline matter	9.4299

The manufacture of Crab Orchard salts has practically come to an end. Its history, at present, is of interest chiefly in indicating the character of some of the ingredients of the clays not brought out by ordinary chemical analyses. The origin of these salts in the Crab Orchard clays has not been investigated. It is difficult to conceive of them as precipitates from the sea during the deposition of the clays. The proportion in which the various ingredients occur is so utterly different from the ratios of their occurrence in the sea. The following table, showing the proportion of the various ingredients dissolved in sea water and obtained by ordinary evaporation of the latter will illustrate this difference.

Chloride of sodium	77.758
Chloride of magnesium	10.878
Sulphate of magnesium	4.737
Sulphate of lime	3.600
Sulphate of potash	2.465
Bromide of magnesium	.217
Carbonate of calcium	.345

For the present it is desired merely to call attention to the fact that these Crab Orchard clays, where impregnated with considerable quantities of Epsom and Glauber salts, occur below or in the vicinity of great masses of Devonian black shale which often contain considerable quantities of iron pyrites. The decomposition of the iron pyrites often results in the production of various sulphates, and possibly some of the sulphates in the Crab Orchard clays may directly or indirectly have had this source.

The Crab Orchard clays may be traced northward into Ohio. Here they were identified by Professor Orton as the Niagara shales. In Highland county this shale, according to the analysis of Professor Wormley, is much more siliceous than the Crab Orchard clay; still farther northward in Ohio, however, the Niagara shale is replaced by a series of thin shaly fragile courses of limestone in which lime and magnesia carbonate predominate greatly. Analyses from these localities are added.

	Highland county	Greene county
Silica	78.00	12.21
Alumina and iron	3.20	8.40
Lime silicate		8.48
Lime carbonate	11.40	34.42
Magnesia carbonate	6.50	30.87
Water combined		5.40
Total	99.10	99.78

4. Silurian Limestones Above the Crab Orchard Horizon.

In Ohio, the Niagara shales, stratigraphically equivalent to the Crab Orchard clays, are overlaid by magnesian limestones known as the Springfield and Cedarville limestones. These are followed by the Hillsboro sandstone, after which there is another series of magnesian limestones, the Greenfield or Monroe bed. Analyses of these rocks as they occur at Hillsboro and Greenfield are appended.

	Springfield limestone	Cedarville limestone	Hillsboro limestone	Greenfield limestone
Silica	13.30	.40	94.10	1.00
Alumina and iron	2.00	1.80	3.60	1.30
Lime carbonate	35.51	54.25	1.30	53.67
Magnesia carbonate	49.87	43.23	.39	42.42
Silicates of lime and magnesia				1.44

Silurian limestones occur above the Crab Orchard clays north of the Licking river in Fleming and Lewis counties. These limestones have not been studied with sufficient care to determine their stratigraphical equivalency with the Ohio divisions, but the following analysis, taken presumably from the large exposures along the river at Vanceburg, is probably of Silurian age and is tentatively referred to the Greenfield or Monroe bed in the Upper Silurian.

2484.—Limestone. Probably from the neighborhood of Vanceburg. Geological position: Probably from the Greenfield bed at the top of the Silurian, at Vanceburg. Sent to John R. Procter by W. J. Richason, of Vanceburg.

A dull-gray, fine-granular rock, with faint lines of stratification.

Analysis. Air-dried.

Moisture and loss	.547	
Insoluble silica and silicates	8.850	
Soluble silica	1.150	
Alumina and iron oxide	2.490	
Phosphoric acid (P_2O_5)	.143	
Lime carbonate	48.790=27.322	lime.
Magnesia carbonate	37.482=17.834	magnesia.
Potash	.490	
Soda	.058	
Total	100.000	

The following analysis appears to be from another Silurian locality, not visited. Judging from the location of this limestone in Lewis county, four miles from Clarksburg, the horizon should be immediately above the Crab Orchard clay.

1085.—Yellow magnesian limestone. Silurian. Salt Lick creek, four miles above Clarksburg, near Valley, Lewis county. Brownish buff porous limestone, full of fossil casts. Exterior surface soft, so as to be scratched by a nail.

Geological position: Probably Silurian, above the Crab Orchard shale horizon.

Water and loss	1.428
Silica and insoluble silicates	2.580
Alumina, oxides of iron and manganese	12.280
Phosphoric acid	.207
Sulphuric acid	.152
Lime carbonate	55.240
Magnesia carbonate	27.820
Potash	.167
Soda	.126

The Chemical Characteristics of the Devonian Rocks of Kentucky, East of the Cincinnati Geanticline.

A. Devonian Limestones.

1. Chemical Analyses.

The Devonian limestone has not been traced north of the Licking river. The following analysis of a bed of limestone immediately beneath the Devonian black shale, near Olympian Springs, in Bath county, probably represents the characteristics of one of the most northern exposures of the Devonian limestone in the State.

1989.—Ferruginous Magnesian Limestone, out of which flows the Chalybeate Spring, and which forms the bed of the Chalybeate Branch, about half a mile north of Olympian Springs.

Geological position: It lies immediately under Devonian Black shale, and probably represents the Devonian limestone. Collected by Robert Peter.

A crystalline-granular limestone; gray, of various tints, in the interior generally light gray; light ferruginous or brownish-ochreous on the exterior.

Analysis. Dried at 212° F.:

Silica	.280
Iron carbonate	11.532
Phosphoric acid	.006
Lime carbonate	54.000
Magnesia carbonate	34.027
Potash	.143
Soda	.040
Total	100.023

In various parts of Clark and Madison counties, and even as far west as Boyle county, there is a layer at the base of the Devonian limestone which contains fish-plates and fish teeth. This was correlated by the former geological survey of Kentucky with the Oriskany. They are here included in the Devonian series of limestones, occurring at their base. Owing to the presence of these fish remains, this thin layer of rock sometimes is rich in phosphoric acid, as the following analyses will show. It is the Kildville layer.

2469.—Phosphatic rock. Stewart Mill, Lulbegrud creek, Clark county. About a mile and a quarter northeast of Indian Fields.

Geological position: Layer with fish remains, at base of the Devonian limestone. Collected by W. M. Linney, July, 1884.

A dark, brown-gray, conglomerate rock, containing many dark-colored fragments of fossil organic remains.

2470.—Phosphatic rock. From near Howard creek, Clark county. Probably west of Indian Fields.

Geological position: Base of the Devonian Limestone. Collected by W. M. Linney, July, 1884.

An impure, ferruginous limestone rock; gray-brown, with ochreous material in spots; contains fossil impressions.

Analyses. Air-dried samples.

	No. 2469	No. 2470
Siliceous residue insoluble in acids	27.580	31.720
Alumina and iron oxide not estimated		
Phosphoric acid (P_2O_5)	9.710	1.842
Lime carbonate	21.380	33.980
Magnesia carbonate	3.055	11.185
Potash	.830	not estimated
Soda	.228	not estimated

Less than a mile from Stuart's mill, down Lulbegrud creek, is the Oil Spring, once a famous water resort. The following analysis is taken probably from a rock belonging to the top of the Devonian limestone at this locality. The dull buff color is very characteristic of the Duffin layer at this exposure.

889.—Rock with oil at base of Black shale, at the Oil Spring, about a mile east of Indian Fields, Clark county. A dark gray limestone with cavities lined with calcareous spar and impregnated with fluid bitumen. Weathered on the surface to a dull buff color.

Geological position: Probably the brecciated or Duffin layer, at the top of the Devonian limestone.

Bituminous matter, water, and loss	7.092
Silica and insoluble silicates	2.480
Alumina, oxides of iron and manganese	11.260
Phosphoric acid	.438
Lime carbonate	56.76
Magnesium carbonate	21.302
Sulphuric acid	.372
Potash	.193
Soda	.103

The following analyses were taken apparently from the base of the Devonian limestone, and from the upper part of this limestone, below the Duffin or brecciated layer.

2197.—Limestone, probably from the vicinity of Elliston, but locality not mentioned.

Geological position: From below the Cauda-galli horizon, at the base of the Corniferous limestone. Collected by John R. Procter.

A fine granular, brownish-gray rock. It gives the odor of petroleum when heated, and probably owes its brownish tint to a small quantity of this substance.

2199.—Impure limestone. Probably from the vicinity of Elliston, but the locality is not mentioned.

Geological position: Top of the Corniferous limestone. Total thickness fifteen feet, with intercalated beds of purer limestone six inches thick.

A tough, fine granular or compact rock. Samples from dif-

ferent levels are mixed; some are brownish-black, some umber colored, and some intermediate in tint.

Analyses. Dried at 212° F.:

	No. 2197	No. 2199
Bitumen, water, and loss	11.287	7.339
Potash	.770	
Soda	.149	
Siliceous residue	22.680	31.990
Lime carbonate	43.060	36.580
Magnesia carbonate	9.994	18.541
Alumina and phosphoric acid	9.420	4.010
Iron peroxide	2.640	1.540
Total	100.000	100.000
Percentage of lime	24.113	20.485
Percentage of magnesia	4.756	8.781

The only building stone known at the locality, from which the following analysis was taken, is of Devonian age.

947.—Building stone. Five miles from Irvine, on the Richmond pike, Estill county. Dark gray, fine grained limestone, with many small scales of mica.

Geological position: Probably Devonian limestone.

Silica and insoluble silicates	18.680
Alumina	.806
Iron oxide	2.360
Iron carbonate	4.321
Manganese, brown oxide	.480
Phosphoric acid	.374
Sulphuric acid	1.471
Lime carbonate	41.380
Magnesium carbonate	30.019
Potash	.482
Soda	.019

A careful study of the Devonian limestone has been made by the present survey at only one locality, at Duffin's cut, half a mile north of Junction City, on the Queen and Crescent railroad. Three samples were analyzed: One from the base of the

Devonian, one from the cherty part above the middle of the section, and one from the brecciated or Duffin layer.

2629.—Devonian limestone, lower 2 feet of section. A compact light gray limestone. The greater part of the sulphur is derived from iron pyrites. This limestone would probably make natural cement, as its analysis is very like that of the Louisville cement rock. Collected by Aug. F. Foerste, at Duffin cut, half a mile north of Junction City, Boyle county.

This limestone is overlaid by dense white limestone, 2 feet thick; baldly weathered limestone, 4 inches thick, quite fossiliferous; dense bluish white limestone, 2 feet 4 inches thick, dense bluish white limestone, 6 inches thick; and dense whitish limestone with considerable chert, 4 feet 8 inches thick. Of the last named part of the section the following analysis was taken.

2630.—Devonian limestone, from the chert part of the section, at Duffin cut. The greater part of the sulphur is in the form of iron pyrites, and the iron is mostly in the ferrous condition, although calculated as ferric oxide in the following statement of results.

Above this cherty limestone there is a dark gray rock, 6 to 8 feet thick, often having a sort of brecciated appearance. This is the Duffin layer and the analysis is given last.

2631.—Brecciated or Duffin layer. A dark gray stone with light, softer patches, giving it a brecciated appearance. It also contains some chert in small imbedded masses. The greater part of the sulphur is in the form of iron pyrites. For separate analyses of the white and dark gray parts of this sample see analyses No. 2632 and 2633 below. Collected at Duffin cut, half a mile north of Junction City, by A. F. Foerste, 1904.

Analyses. Air-dried samples. Devonian Limestones.

	Base No. 2629	Cherty layer No. 2630	Duffin layer No. 2631
Moisture	.14	.09	.06
Ignition (combined water, volatile matter, and carbon dioxide	35.46	44.79	41.92
Silica	20.02	2.14	7.74
Alumina	3.23	1.24	2.73
Ferric oxide	1.36	2.34	2.04
Lime	24.06	31.96	29.66
Magnesia	14.62	17.84	14.65
Potash, soda, and lithia	Traces	Traces	Traces
Phosphorus pentoxide	.37	.06	.09
Sulphur trioxide	1.06	.45	.51
Total	100.32	100.91	99.40
Sulphur calculated from the sulphur trioxide	.42	.18	.20
Iron pyrites equivalent to total sulphur	.79	.34	.38

As a means of comparing the white component of the Duffin layer with the dark gray component, the following analyses are added. The white color is found in the small more or less angular blotches which give the brecciated appearance to the rock. The dark gray color is characteristic of the body of the rock, aside from the small light colored blotches just mentioned.

2632.—The white component of the Brecciated or Duffin layer, obtained by carefully breaking it out from the gray body of the rock. The white part appeared to constitute only about a fourth of the original rock. It was separated in a fair state of purity. The greater part of the sulphur is in the form of iron pyrites, and the iron is in the ferrous condition. This analysis resembles No. 2630 rather closely. Collected at Duffin cut, north of Junction City, Boyle county, by A. F. Foerste, in 1904.

2633.—The dark gray component of the brecciated limestone or Duffin layer, exclusive of the chert, obtained by carefully breaking it out. It was found impossible to separate the gray

entirely from the white. The greater part of the sulphur is in the form of iron pyrites and the iron is in the ferrous condition. From Duffin cut, collected by A. F. Foerste, in 1905.

Analyses of components of Duffin rock. Air dried:

	White blotches No. 2632	Dark gray body of rock No. 2633
Moisture	.05	.08
Ignition (combined water, volatile matter and carbon dioxide	44.42	42.46
Silica	3.18	6.86
Alumina	.76	1.40
Ferric oxide	3.62	2.94
Lime	31.04	29.58
Magnesia	17.22	16.25
Potash, soda, and lithia	Traces	.39
Phosphorus pentoxide	.06	.08
Sulphur trioxide	.26	.66
Total	100.61	100.70
Sulphur calculated from the sulphur trioxide	.10	.26
Iron pyrites equivalent to the sulphur	.19	.50

It is evident from the preceding analyses that the Duffin layer consists of a very typical dolomite, the ideal dolomite consisting of 30.4 per cent. of lime and 21.7 per cent. of magnesia. In the field, the Duffin layer often has a deep brown color and appears to be full of small angular fragments, chiefly less than half an inch in diameter. It then resembles a volcanic ash or tuff, but the chemical analysis is entirely against such an origin. The cause of the brecciated appearance has not been determined.

At some localities the Duffin layer appears to form a part of the Devonian black shale series; at other localities true limestones occur at horizons thirteen to twenty feet above the base of the black shale. Several analyses made under the preceding survey are added here, owing to the possibility of their affording a clue to some one interested in some special line of investigation. The precise horizon from which the rocks analyzed were obtained is not known, but is sufficiently indicated to afford a clue as to their probable location.

2198.—Bituminous limestone, from near Elliston.

Geological position: From above the Corniferous limestone. Bed, three to ten feet thick. Collected by John R. Procter. Possibly the brecciated appearing limestone or Duffin layer.

Generally of a dull, brownish-black color. Some pieces with bands of a lighter gray tint. It is a fine granular rock.

2200.—Limestone, on the road one mile south of Mrs. Susan Jane Embry. A little over two miles south of Waco, on the road to Brassfield, a lane turns off westward from the road and then angles off irregularly toward Searcy station; a short distance westward along this lane Mrs. Embry used to live.

Geological position: Intercalated with the so-called Black band or bituminous limestone. Collected by John R. Procter. Possibly the brecciated layer or Duffin layer.

A dull buff-gray, fine granular rock, with some little infiltration of hydrated iron oxide.

Analyses. Dried at 212° F.:

	No. 2198	No. 2200
Water and loss		6.117
Bitumen, water, and loss, potash and soda	13.022	not estimated
Siliceous residue	20.990	18.190
Alumina and phosphoric acid	9.040	10.980
Iron peroxide	1.890	
Lime carbonate	41.150	47.580
Magnesia carbonate	13.908	17.133
Total	100.000	100.000
Percentage of lime	23.044	26.645
Percentage of magnesia	6.384	8.158

888.—Limestone. From the base of the Black slate series, in Clark county. The dense calcareous portion of the gray black slate. Found also in Madison, Bath, Powell, Estill counties.

Geological position: Possibly the brecciated or Duffin layer.

this comparatively small section of limestone is likely to be entirely too cherty to be of use commercially. Locally, however, considerable sections are known which are comparatively free from chert. Some of the localities near Elliston, and others several miles northeast of Waco, in Madison county, are known to be comparatively free from chert and yet to show about twenty feet of rock which might be commercially available. Other localities exist near Crab Orchard, and several of these are very favorably situated as regards railroad facilities. No chemical analyses have been made so far however.

Under the term natural cements a great variety of cements are included. In the manufacture of natural cements no attempt is made to remedy any of the defects of the natural rock. There is no mixture of materials, but whatever rock is selected for manufacture is burned without mixing or preliminary grinding. As in the case of Portland cement, the essential elements again are the lime, silica, alumina, and ferric oxide, but the rock is always burned at a lower temperature than Portland cements, the mass of the rock in the kiln is never hot enough to even approach the fusing or clinkering point which is essential in the manufacture of Portland cements. The lime combines with the silica, alumina, and ferric oxide, forming various silicates, aluminates, and ferrites of iron, but the natural cements set more rapidly than Portland cement and ultimately do not attain so high a degree of strength.

Limestones used for the production of natural cements invariably are clayey, containing from 13 to 35 per cent. of clayey material (alumina and silica), of which 10 to 22 per cent. is silica, while alumina and ferric oxide together may vary from 4 to 16 per cent. Since a great variety of clayey limestones will produce natural cement on burning, it is evident that rocks favorable for this purpose must be comparatively common and widely distributed. For this reason, also, natural cements are likely to be comparatively cheap and must find a market near home, usually within the boundaries of the State producing them.

In the production of these natural cements a much higher percentage of magnesium carbonate is permissible. In the limestones used for the manufacture of the so-called Louisville cements, the percentage of magnesium carbonate varies from

Water and loss	48.762
Impurities	1.000
Aluminum sulphate	25.585
Iron sulphate	15.653
Magnesium sulphate	1.000
Alkaline sulphates	8.000

These sulphates go into solution in the waters percolating through the black shales, and issue at springs to which they may give a more or less distinct flavor. Many other substances are taken up, some of them in sufficient quantities to be readily detected on analysis. It has been stated that the table of contents of the waters from a mineral spring is but an index of the various geological strata through which its waters have passed and of the mineral bodies with which they have come in contact. In this sense, the Devonian black shales should be of special interest to the people of Kentucky, since a considerable part of the springs which are visited, more or less, for their medicinal virtues issue from the black shales. Among these may be mentioned the Fox springs, eight miles east of Flemingsburg, in Fleming county; the Olympian springs, in the southeastern part of Bath county; the Oil springs, about a mile northeast of Indian Fields, in the northeastern part of Clark county; the Estill springs, about a mile north of Irvine, in Estill county; Hale's well, about four southeast of Stanford, in Lincoln county; the Linietta springs, northwest of Junction City, in Boyle county; Alum springs, two miles farther west in Boyle county; the Sulphur springs, three miles southeast of Lebanon, in Marion county; and numerous other springs, less known but with waters containing the same ingredients.

For convenience, mineral waters may be divided into several classes. *Alkaline* waters are those which contain as principal ingredients the carbonates of the alkaline earths, calcium and magnesium, and the carbonates of the alkalies, potassium and sodium. Waters of this class usually contain considerable sodium carbonate and calcium carbonate, and small amounts of the chlorides and sulphates. If much sodium carbonate is present, the water has a greasy touch. Such waters are regarded as diuretic, producing an increased flow of urine, and so may be of service in flushing the system and in helping to get rid of accumulated waste products. *Saline* waters contain as prin-

cipal ingredients the sulphates or chlorides of calcium, magnesium, aluminum, potassium and sodium. Sodium chloride is the most common ingredient of such waters, but magnesium sulphate (Epsom salt) and sodium sulphate (Glauber salt) occur in most waters of this class. Sodium carbonate, on the contrary, occurs only in very small quantity as a rule. Sodium chloride waters are said to be useful in stimulating the gastric mucous membrane, in increasing the appetite, and in getting rid of excessive amounts of secreted mucus. The best results are obtained in gastritis. Saline waters containing considerable quantities of magnesium and sodium sulphate are purgative. *Chalybeate* waters contain as their principal ingredients the salts of iron, especially iron bi-carbonate. On coming to the surface at the spring, this bi-carbonate gives up the carbonic acid and takes up oxygen. It thus is changed to iron oxide which precipitates or settles as a brownish-yellow sediment. This sediment is seen not only at the spring but also for some distance along the stream leading away from the spring. Such waters are often recommended for patients suffering from anemic or chlorotic conditions. Iron compounds, if taken in sufficient quantities, or for a long time, may cause constipation and other disturbances of the digestive system, but usually they occur in too small a quantity in the mineral waters to cause any injury.

Sulphur waters are those which contain a sufficient quantity of hydrogen sulphide to be readily recognized by the smell. The same gas is present in rotten eggs and hence waters containing sulphuretted hydrogen often are said to smell and taste like rotten eggs. On reaching the surface at the spring, much of the hydrogen sulphide escapes. When brought in contact with the oxygen of the air, the gas in part is dissociated into its elements and the sulphur is deposited as a white or whitish-yellow sediment upon surrounding objects, while the hydrogen unites, with the oxygen to form water. Wells containing this deposit often are known as *white-sulphur* wells. When salts of iron are present, the free sulphur may unite with the iron to form black flakes of iron sulphide, resulting in a black sediment, and giving rise to the name *black--sulphur* wells. As far as known, hydrogen sulphide does not have any pronounced medicinal value when taken into the stomach. Waters contain-

ing hydrogen sulphide in notable quantities usually are more or less saline and the medicinal virtues of these waters is due to their saline contents and not to the gas. The bad smell of the water is not an index of its medicinal value.

All of these classes of springs are represented among the springs issuing from the Devonian black shale, as may be seen by an examination of the following partial records of analyses, in which only the principal ingredients are recorded. Most of these analyses were made so long ago that a special report on the mineral springs of the Devonian black shale belt is now desirable. A report bringing together all available information on the mineral waters of Kentucky, and accurately defining their mineral ingredients, would be of material assistance to physicians in recommending to their patients the use of waters from particular springs. In the following analyses the figures state the number of parts of the ingredients found in a total of 1,000 parts of water.

ALKALINE AND ALKALINE SALINE SPRINGS.

LOCATION, NAME AND CHEMICAL NATURE OF SPRING	Indian Fields, Clark County, Soda Spring, Alkaline, Saline	Olympian Springs, Bath County, Tea Water, Alkaline, Saline	Olympian Springs, Kitchen Well, Alkaline, Saline	Olympian Springs, Black Sulphur Water, Sediment nearly black, Alkaline, Saline	Olympian Springs, White Sulphur Water, Alkaline, Saline	Junction City, Boyle County, Black Sulphur Water sediment black, Alkaline, Saline, slightly Chalybeate	Alum Springs, Boyle County, Black Sulphur Water, Alkaline, Chalybeate	Junction City, Linney's Well, Black Sulphur Water, Alkaline, Saline, with Epsom Salt	Fox Springs, Fleming County, White Sulphur Water, Alkaline, Saline, with Glauber Salt	Indian Fields, Red Sulphur Water, Alkaline, Saline, Calcareous	Alum Springs, Petroleum Spring, Calcareous
No. of analysis	2474	1992	1991	1985	1986	2274	2275	2276	2658	2474 bis.	2277
Soda carbonate	.5266	.4479	.5431	.3247	.3113	.5089	.0870	.288	.0538	.033	
Lime carbonate		.0241	.0556	.0158	.0744		.0396	1.490	.0982	.156	.0151
Magnesia carbonate			.0277				.0216		.0430	.051	.0278
Iron carbonate						.0097	.0342				
Soda chloride	.0371	.0377	.1483	.1208	.1326	.1204		.247	.0427		
Magnesia chloride	.0159									.067	
Calcium chloride											.0086
Soda sulphate			.0208			.1841			.0460		
Potash sulphate			.0285			.0164		.192			
Lime sulphate	0.265							.267		.038	.0408
Magnesia sulphate								.160			

EPSOM AND GLAUBER WATERS.

Location, name and chemical nature of springs	Junction City, Boyle County, Knott's Spring, Glauber, Epsom	Lebanon, Marion Co., Harrison Spring, from Waverly Bed, Epsom, Glauber	Indian Fields, Grove's Well, from Crab Orchard Bed, Epsom, Glauber	Junction City, Fale's Epsom Spring Epsom Glauber, Chalybeate	Olympian Springs, Chalybeate Spring, Brownish-orange sediment, Epsom, Glauber	Junction City, Procter's Well, Epsom, Glauber	Olympian Springs, Bath County, Main Chalybeate Spring, Ferruginous-brown sediment, Epsom, Chalybeate	Fox Spring, Fleming County, Chalybeate Water, Epsom, Glauber, Chalybeate
No. of analysis	2279	2897	2471	2278	1988	2280B	1987	2657
Magnesia sulphate	.930	4.014	4.7776	3.124	.0693	.128	.1170	.0485
Soda sulphate	1.624	1.658	.7118	.152	.0238	.112		.0124
Lime sulphate	.001	1.109	3.2610	1.766	.0366	.240	.0554	.0183
Potash sulphate				.249				
Iron sulphate								.0175
Iron carbonate				.102			.0242	.0130
Lime carbonate			3.740	.198	.0890	.118	.0998	
Soda chloride							.0308	

SALT SPRINGS.

LOCATION, NAME AND CHEMICAL NATURE OF SPRING.......	Junction City, Boyle County, Salt Well, Saline.........	Olympian Springs, Bath County, Salt Sulphur, Yellowish or Ochreous Incrustation, Saline.......	Olympian Springs, Bath County, Salt Water, Saline......	Indian Fields, Clark County, Oil Spring, Saline..........
No. of analysis....................	2280	1984	1990	2472
Soda chloride......................	13.878	4.8997	4.7121	.0973
Magnesia chloride..................		.1089	.1188	.0845
Potash chloride....................		.0355		
Lime carbonate.....................	1.454	.1975	.1844	.1198
Magnesia carbcnate.................	1.367	.0506		
Soda carbonate.....................			.2241	
Lime sulphate......................				.0583

ALUM AND CHALYBEATE SPRINGS.

LOCATION, NAME AND CHEMICAL NATURE OF SPRING	Junction City, Boyle County, Alum Water, Alum, Epsom.......	Junction City, Chalybeate Well, Copperas, Epsom, Glauber.	Indian Fields, Chalybeate Spring, Alum Chalybeate........	Alum Springs, Boyle County, Old Chalybeate Spring, Chalybeate..........	Alum Springs, Phosphorus Spring, Chalybeate.......
No. of analysis..........	2273	2270	2473	2271	2272
Alumina sulphate.......	5.3477		.0586		
Iron sulphate...........	2.6761	.1977			
Potash sulphate........	?	.0235	.0119	.0140	.0140
Lime sulphate..........	.4994	.2917	.0432		
Magnesia sulphate......	.1350	.2250			
Soda sulphate...........		.1521			
Iron carbonate..........			.0192	.1862	.1654
Lime carbonate.........				.0199	.0307
Magnesia carbonate.....				.0093	.0133
Soda chloride...........			.0162		

In the case of the Alkaline springs, those in which sodium carbonate is the chief ingredient predominate. Springs of this type occur northeast of Indian Fields, and near the Olympian Springs. Those at Junction City and at Fox Springs contain not only sodium carbonate but also appreciable quantities of the sulphates of sodium and magnesium.

Some saline springs contain sodium chloride in quantities so much greater than that in which the other ingredients occur that the name salt springs or salt wells appears most appropriate. One well at Junction City, and two at the Olympian Springs are good examples of these wells. Magnesium chloride, and also the carbonate of sodium or magnesium, or both, also occur. A well containing a considerable quantity of salt occurred at the crossing of the Cincinnati Southern railroad over Green river, and another is found just east of the depot at Crab Orchard.

In one of the wells, at Junction City, the sulphate of soda or Glauber salt predominates, although the sulphate of magnesia or Epsom salt also occurs in considerable quantities. Usually the conditions are reversed and Epsom salt predominates very much. Wells of the latter class occur at Lebanon, Indian Fields, Junction City, Olympian Springs; and one at Fox Springs shews a slightly greater quantity of magnesium sulphate. The well at Lebanon issues from the base of the Waverly series, from the lower part of the Linietta or Bedford clay shales. The one at Indian Fields is in the Crab Orchard bed. The wells at Olympian Springs issue from the crevices in the Devonian limestone, at the base of the Devonian black shales. The water at Fox Spring issues from near the top of the limestone underlying the Devonian black shale. From this it may be seen that saline springs in which the sulphates of magnesia and sodium are the chief ingredients are more common in the ordinary clays of the Crab Orchard and Waverly beds, and in the accompanying limestones, than in the carbonaceous Devonian black shales.

Waters containing more or less alum and copperas are more common in the Devonian black shales than is indicated by the accompanying analyses. The analyses have not been made with the view of determining what percentage of the saline material is in the form of alum. The carbonate of iron occurs in small quantities in quite a large number of the springs which have

been examined. In only two springs, however, is iron carbonate the chief ingredient, and both of these occur at Alum Springs, a short distance east of Junction City, on the Knoxville branch of the Louisville and Nashville railroad.

Such traces of life as have been found in the Devonian black shales have been chiefly of vegetable origin and on this account the bituminous matter in these shales is believed to be chiefly of vegetable origin. The large accumulations of oil at Ragland and Irvine may have had an entirely different origin. The mineral part of the shales does not show any close agreement with the materials forming the Crab Orchard clays, from which, indeed, they are separated in the greater part of the area under discussion by the Devonian limestone. As compared with the Crab Orchard clay, the black shales show more silica and lime, and less alumina and potash. The reasons for these differences have not been determined.

The Devonian black shales, in their original condition, are useful chiefly as road material. Although very little intelligence is shown usually in the use of this material for roads, during a large part of the year the black shale roads are in excellent condition. When greatly decayed and reduced to clay, the Black shale is serviceable for the manufacture of vitrified brick.

The Chemical Characteristics of the Lower Waverly Rocks.

A. Linietta or Bedford Clay Shales.

At the base of the Linietta or Bedford clay shales, at the bottom of the Waverly series of strata, phosphatic nodules occur very frequently and over a wide area. Usually they are confined to a few inches at the base of the series, although ranging sometimes for several feet. They often contain fossil remains, usually some shell or the fragment of some fish remain. The following analysis indicates at least the presence of considerable phosphatic material.

2281.—Phosphatic nodules, Boyle county. Probably from the neighborhood of Junction City.

Geological position: From the base of the Linietta or Bedford clay shales, at the base of the Waverly series. Collected by William M. Linney, Oct. 17, 1882.

Shapes generally oblong, spheroidal or ovoid, somewhat flattened. Exterior of a dull brownish-gray color; interior darker and irregularly cellular. Some of them contained fragments of fossil bones.

On examination they were found to contain bituminous matter, ferrous carbonate, and a considerable proportion of phosphates, which in one analysis gave 29.10 per cent. of phosphoric acid (P_2O_5).

At the base of the Waverly series of strata there is a great mass of clays, here called the Linietta clay, which occupies about the same horizon as the Bedford formation of Ohio and the New Providence shale of Indiana. Northward, toward the Ohio river, this clay section is replaced by arenaceous shales interbedded with fine-grained sandstones or *freestones*. The analyses of the Linietta clays are fairly represented by those cited below.

2597.—Linietta or Bedford clay. From Blue Lick, Madison county. From Berea, 1.5 miles on Kingston pike, then 1.5 miles east to junction with Blue Lick pike. Southwest of road corner. Geological position: 0 to 40 feet, at base of Waverly. Collected by A. F. Foerste, 1904.

Analysis of air-dried sample:

Moisture	1.75
Ignition (combined water, etc.)	4.29
Silica	65.58
Alumina	16.00
Ferric oxide	5.21
Lime	.03
Magnesia	1.25
Potash	3.89
Soda	.82
Titanium dioxide	1.13
Sulphates and phosphates	Traces
Total	99.95

2499.—Clay. On the land of John Pigg, three miles northeast of Berea, two miles south of Bobtown, near the road from Berea to Bobtown, at the Blue Lick. Locality: R-S-8. Geological position: Linietta or Bedford clay shale at base of the Waverly series. Collected by Moritz Fischer, August 16, 1884.

Analysis of air-dried sample:

Hygroscopic moisture	1.030
Combined water and loss	2.947
Silica	68.440
Alumina and iron oxide	20.180
Lime carbonate	.144
Magnesia carbonate	2.860
Potash	3.678
Soda	.740
Phosphoric acid (P_2O_5)	A trace
Total	100.000

Pulverized and kneaded with water, it would be plastic enough to be used for common pottery-ware.

2618.—Analysis of clay, Junction City, Boyle county, Ky. Geological position: Linietta or Bedford clay, at base of Waverly series. Blue Lick, northwest of Linietta Springs, northwest of Junction City about one-half mile. A. F. Foerste, 1904.

Analysis of air-dried sample:

Moisture	1.35
Ignition (combined water, etc.)	4.85
Silica	62.44
Alumina	17.87
Ferric oxide	6.31
Lime	.18
Magnesia	1.18
Potash	3.52
Soda	.77
Titanium dioxide	1.04
Sulphur trioxide	.19
Total	99.70

1873.—Clay. From the headwaters of Green river, on the land of Thomas W. Varnon. Bed two to four feet from the surface, and said to be forty-two to forty-five feet thick; resting on Black shale which is fifty feet thick. Salt water is found by boring at a depth of eighty-four feet, and some little petroleum in the sandstone. Collected by Senator Varnon.

Geological position: From the Linietta or Bedford clay shale, forming the base of the Waverly series.

Clay imperfectly laminated, of a dark olive-gray color. Burns to a gray-buff color. The considerable proportions of the iron oxide, lime, potash, and soda prevent this clay from being refractory in the fire; but while it is therefore unfit for the manufacture of fire-brick, it will yet answer well for ordinary pottery, terra cotta work, and tiles.

Analysis, dried at 212 degrees F.:

Water and loss	5.705
Silica	61.580
Alumina	23.946
Iron protoxide	5.814
Phosphoric acid	Not Det.
Lime	.201
Magnesia	.850
Potash	1.542
Soda	.362
Total	100.000

As compared with the Crab Orchard clay, these clays at the base of the Waverly series contain more silica, about the same amount of alumina and iron, and a less quantity of lime, magnesia, and potash. These clays contain too much iron to be serviceable as stoneware clays. They contain, however, enough iron and alkalies, and are sufficiently low in lime and magnesia to make excellent clays for vitrified ware, paving brick, sewer pipe and the like. They will burn to a cherry red color, and would serve also for the manufacture of ordinary brick. Owing to the larger percentage of silica, the Linietta or Bedford clays should be more serviceable than the Crab Orchard clay for the manufacture of Portland cement. The clay from the Blue Lick locality, for example, conforms quite closely to the formula that the sum of the alumina and the iron oxide shall equal about a third of the silica, and the requirement that the silica shall equal at least 55 per cent., and preferably should be between 60 and 70 per cent.

B. Upper Layers of the Waverly Series.

No attempt has been made to study the upper layers of the Waverly series in east-central Kentucky. In the vicinity of Vanceburg, on the Ohio river, at Alum Rock, the thickness of the arenaceous clay shales and interbedded sandstones, representing the Bedford formation of northern Ohio, is approximately 90 feet. This is overlaid in succession by Berea sandstone, 21 feet thick; thin black argillaceous Sunbury shale, 13 feet thick, and other shaly and sandy layers, representing the Cuyahoga shales. None of these overlying layers can be recognized as distinct formations in east-central Kentucky. The freestone layers at Irvine, and those quarried at Berea occur fully 350 feet above the top of the Devonian black shale. This, probably, is the horizon also of the Farmer station sandstone.

2429.—Sandstone. From the quarry near Farmer Station, on the Chesapeake & Ohio Railroad, thirty-five miles beyond Mount Sterling. Collected by W. W. Monroe.

Geological position: Probably from the upper part of the Waverly series, 350 feet above the base of the series.

A fine-grained sandstone of a handsome light gray color on the recently exposed surfaces, showing a few minute spangles of mica. Stained light ochreous and brownish on the weathered surfaces. Showing no fossil remains, except Taonurus caudagalli on one of its surfaces. This rock was used in the construction of the court-house at Lexington in 1882. It is composed of fine grains of transparent, colorless quartz united by a cement composed of carbonates of iron, lime, and magnesia, with a little silicate of alumina.

Analysis; sample air-dried:

Moisture and loss	2.514
Sand and insoluble silicates	93.128
Alumina, phosphoric acid and loss	1.188
Iron carbonate	2.336
Lime carbonate	.578
Magnesia carbonate	.256
Total	100.000

2498.—Plastic clay. From the land of Gordon Glasgow, on the slope of Bear Mountain, three miles southeast of Berea, Madison county.

Geological position: Collected by Moritz Fischer, July 1, 1884, and labeled as: Clay in the Waverly series, near the Conglomerate. This probably is a clay member of the Pennington shale, near the Rockcastle conglomerate, above the Lower Carboniferous limestone, and occurs about 600 feet above the base of the Waverly.

A light gray, plastic clay. Calcines to a light reddish color. This clay could be used for the manufacture of various kinds of common pottery ware, terra cotta products, and the like.

Analysis of air-dried sample:

Water and loss	20.014
Silica	48.000
Alumina	18.380
Iron peroxide	3.900
Lime carbonate	1.600
Magnesia carbonate	4.033
Potash	3.797
Soda	.276
Total	100.000

The Chemical Composition of the Irvine Clays.

Probably no class of clays in the central parts of Kentucky have aroused a wider interest for a longer time than those from the Irvine formation in various parts of Madison county. From no area of similar small size have we as many analyses. This is due to the fact that at an early date a fairly extensive production of common stone-ware was founded upon the use of this clay, and that this stone-ware industry is still in existence.

Stoneware differs from common earthenware chiefly in the fact that earthenware is burned merely until it reaches the stage of incipient vitrification but remains porous, while in the case of stoneware the clay is burned to vitrification so that the body of the ware becomes impervious to moisture. The color of the body may be reddish, buff, or bluish black, but this color frequently is concealed by a coating of salt glaze or slip. Stoneware is made usually from refractory or semi-refractory clays, the best results often being obtained by mixing different clays.

One of the clays is used to supply stiffness to the body in burning, while the other supplies the fluxing qualities and serves to bind the ware together. The fusible impurities must be of such a character as to cause the body to attain a state of incipient fusion while the slip or glaze at the same temperature will melt.

When the ratio of alumina to ferric oxide equals 7 to 1 the resulting stoneware is not colored red by the ferric oxide, but takes on a yellowish color, which becomes yellowish-white or nearly white as this ratio approaches 13 to 1. Clays of this kind could be used also for the manufacture of light or buff brick.

Chemical analyses usually show the following range of variation:

	Maximum	Minimum	Average of 8 analyses
Silica	72.10	45.00	64.08
Alumina	38.24	19.08	23.86
Ferric oxide	1.50	0.96	1.23
Lime	1.70	....	0.78
Magnesia	0.68	0.11	0.40
Soda	Trace	....	Trace
Potash	2.42	0.15	1.48
Water	14.80	6.25	7.78

Among the earlier analyses of the stoneware clays of Madison county are the following:

946.—Potter's clay. Four miles northwest of Irvine, on the Richmond pike. Light buff-gray, with stratified lines of reddish. Appears to be principally fine quartzose sand with a few minute sparkling specks of mica.

Geological position: Irvine formation.

Water expelled at red heat	4.400
Silica	71.780
Alumina	17.580
Iron oxide	2.420
Lime	None
Magnesia	.547
Potash	2.271
Soda	.322
Sulphuric acid	.112
Loss	.568

1122.—Potter's clay, near Waco.
Geological position: Irvine formation.
Analysis:

Water expelled at red heat	6.140
Silica	62.58
Alumina	21.98
Iron oxide	4.78
Brown oxide of manganese	Trace
Phosphoric acid	Not Est.
Sulphuric acid	.234
Lime	Trace
Magnesia	1.276
Potash	2.607
Soda	.500

In sample No. 946, the ratio of alumina to ferric oxide is about 7 to 1 and the clay should burn to a buff color. The percentage of silica is rather high, and the clay should prove more refractory than sample No. 1122. In the latter case the ratio of the alumina to ferric oxide is about 5 to 1 and the color of the burned clay should be darker.

Two additional analyses of the potter's clay at Waco were published in 1877.

1876*a*.—Potter's clay, quality No. 1. Light gray soft clay.
1876*b*.—Potter's clay, quality No. 2. Of a bluish-gray color.
Both clays from the neighborhood of Waco. These are good clays for ordinary stoneware.

Analyses; dried at 212 degrees F.:

	No. 1876*a*	No. 1876*b*
Combined water and loss	7.020	10.531
Silica	59.976	56.960
Alumina, iron and manganese oxides, and phosphoric acid	27.640	28.740
Lime carbonate	.280	.200
Magnesia	.606	.752
Potash	3.931	2.502
Soda	.547	.315
Total	100.000	100.000

These samples do not differ greatly from No. 1122, although the percentage of silica is less. Possibly the inferior quality of

the sample said to be of quality No. 2 was due to its vitrifying at a lower temperature, due to a smaller percentage of silica and a larger percentage of iron.

In 1879 two additional analyses were published, presumably from clay used for the manufacture of stoneware. Bybeetown is now known as Portland, and is still the seat of stoneware manufacture. The Oldham locality is believed to have been on the Bybeetown side of Waco.

2168.—Clay. From near Bybeetown or Portwood. Milton Barlow. Bed four feet thick, overlying Black shale.

Geological position: Probably from the Irvine formation. Collected by John R. Procter.

Clay of a light, warm drab-gray color. Irregularly and imperfectly laminated. Quite plastic. Burns to a delicate light reddish-cream color, nearly white.

2169.—Clay of workable thickness; on the road leading from Waco to R. Oldham; about a mile and a half from Waco.

Geological position: Collected by John R. Procter, and stated by him to occur probably below the Corniferous limestone. The exact locality not being known, this statement can not be verified, but, in this area, plastic clays with a very small percentage of lime are not known in Silurian formations.

A compact clay, generally of a light, olive-gray color, stained irregularly with ochreous and ferruginous. Quite plastic. Calcines quite hard, to a handsome light brick color.

Analysis; sample dried at 212 degrees F.:

	No. 2168	No. 2169
Water and loss	6.973	5.166
Silica	62.560	64.566
Alumina	24.780	20.160
Iron peroxide	1.800	4.200
Lime	A trace	.213
Magnesia	.317	.641
Potash	3.276	5.054
Soda	.294	Not Est.
Total	100.000	100.000

Regarding these clays, Dr. Robert Peter, the chemist of the Survey, made the following remarks:

These are good plastic clays for the manufacture of ordinary pottery ware, as well as for ornamental articles of terra cotta, for which they are adapted because of the pleasing tints which they assume on calcination. They owe these tints to their considerable proportion of iron oxide, which, together with their large proportion of potash renders them unavailable as fire-clays. This very circumstance, however, may fit them for stoneware and for superior kinds of hard-burnt, semi-fused, ornamental pottery in the hands of skillful workmen and artists.

The ratio of alumina to ferric oxide in sample No. 2168 is about 13 to 1, and the clay should burn to a nearly white color. In sample No. 2169, this ratio is about 5 to 1, and the clay should burn to a distinctly brick-red color. The percentage of potash is large, and the clay should flux at a distinctly lower temperature than any so far mentioned. This should cause it to be regarded as an inferior clay.

In 1884, the following analyses were published, showing that the interest in stoneware clay still focussed around Bybeetown and Waco, in Madison county.

2496.—Clay. From the land of James Walker Lewis, two miles southeast of Bobtown, about one hundred yards to the left of the Big Hill pike, almost opposite the blacksmith shop.

Geological position: Bed four to five feet thick, resting on Silurian clay shale. Sample of the upper ten inches. Collected by Moritz Fischer, June 21, 1884. The Silurian clay shale at this locality is the Lulbegrud clay division of the Crab Orchard bed. The overlying clay, of which the analysis is given, probably belongs to the Irvine formation. Locality: R-S-22.

A laminated clay or soft shale, of a light gray color on the exterior; darker colored and brownish-yellowish-gray in the interior.

2497.—Clay. From the same locality as the preceding. Sample from ten to twenty inches below the surface. Collected by Moritz Fischer.

Geological position: Apparently from the Irvine formation, but the large percentage of lime is more suggestive of Silurian clays.

Darker colored than the preceding; of a light olive green color.

No doubt common pottery ware and terra cotta could be made of this clay, ground and properly tempered with water. It contains too much potash, lime, and iron oxide for a fire-clay.

Analysis of air-dried samples:

	No. 2496	No. 2497
Water, carbonic acid, and loss	8.091	15.548
Silica	59.000	42.560
Alumina and iron oxide	24.640	20.980
Lime	1.456	8.680
Magnesia	1.096	7.247
Potash	5.500	4.819
Soda	.217	.166
Titanic acid	....	Trace
Total	100.000	100.000

Sample No. 2496 contains 20.68 per cent. of alumina and 3.96 per cent. of iron peroxide.

As compared with other clays from the Irvine formation, the percentage of lime in sample No. 2496 is rather high, and the same may be said of the percentage of magnesia and potash. In this respect the clay approaches some of the Crab Orchard clays. The ratio of alumina to ferric oxide is about 5 to 1, and the clay should burn to a light brick-red color. It should fuse at a much lower temperature than the potter's clays hitherto mentioned, with the exception, perhaps, of sample No. 2169. Sample No. 2497 is utterly at variance with any other clay known in this part of Kentucky. It has a low percentage of silica and a high percentage of lime and magnesia compared with the clays so far investigated. It should not prove sufficiently refractory to make a good stoneware clay. The age of these clays is not definitely known.

Several analyses have been made for the present survey. The following analysis is taken from a sample of the clay used by the firm of D. Zittel & Son, manufacturers of common stoneware, about half a mile east of Waco. The clay is obtained from the McKinney farm, southeast of Waco.

2615.—Clay, Waco, Ky., on G. S. McKinney's land, Madison county, Ky.

Geological position: Irvine bed. Thickness, 3.5 to 5 feet.

A. F. Foerste, 1904. From Waco, one-fourth miles south, one-fourth mile east. Pit on south side of road.

Analysis of air-dried sample:

Moisture	2.27
Ignition (combined water, etc.)	5.85
Silica	63.76
Alumina	19.36
Ferric oxide	2.59
Lime	.40
Magnesia	.82
Potash	2.86
Soda	.47
Titanium dioxide	1.25
Sulphuric anhydride	Trace
Total	99.63

In this case the ratio of the alumina to the ferric oxide is about 7.5 to 1, and the clay burns to a light buff color. It is used at present for jugs, jars, churns, and the like, but apparently might be made useful also for architectural terra cotta, chemical stoneware, clay pipes, and the like, although not very refractory clay. In this respect it is surpassed by the white clay from the Adams farm, next to be described. This clay contains more alumina, and less ferric oxide, lime and magnesia. The percentage of alumina to ferric oxide is about 19 to 1, and the clay burns to a very light color. On this account it should be valuable for architectural terra cotta and for light colored pressed bricks, especially for those which are artificially colored or speckled by the use of manganese or other metallic oxides.

2635.—White clay, on the Adams farm, near Waco, Madison county. Color, nearly white, banded in places with brown. Found at the same locality as No. 2636.

Geological position: Irvine bed. Collected by A. F. Foerste, in 1904.

Analysis of air-dried sample:

Moisture	1.60
Ignition (combined water and volatile matter)	6.74
Silica	61.00
Alumina	23.68
Ferric oxide	1.21
Lime	.20
Magnesia	.68
Potash	3.09
Soda	.43
Titanium dioxide	1.39
Sulphur trioxide	Trace
Total	100.02

At present the Adams farm clay is used at the tiling factory, at Searcy Station, in the manufacture of roofing tiles. It is mixed with the clay which comes from the immediate vicinity of the factory, and probably serves to bind the latter together. The following analysis indicates the nature of the resulting mixture, consisting chiefly of clay obtained from the pit at the factory:

2634.—Tiling factory clay. Obtained north of the factory, at Searcy Station, about a mile southeast of Moberly. The sample consisted of broken, unburned roofing tiles. It was buff colored and uniform in appearance.

Geological position: Irvine bed. Chiefly alluvial. Directly above the Devonian black shale. Collected by A. F. Foerste, in 1904.

Analysis of air-dried sample:

Moisture	1.75
Ignition (combined water and volatile matter)	4.26
Silica	73.78
Alumina	13.23
Ferric oxide	1.24
Lime	.54
Magnesia	.82
Potash	2.27
Soda	.50
Titanium dioxide	1.25
Sulphur trioxide	Trace
Total	99.64

This clay mixture contains more silica and less alumina than any so far described. It is not used for stoneware, but only for roof tiling, drainage tiling and brick. The roofing tiles are burned to a light red color, but those so far put out appear underburned.

The following analysis shows the nature of the clay used at the Searcy roofing tile factory as fire-clay.

2636.—Fire-clay, used by Searcy at the roofing tile works. Obtained from the Adams farm, near Waco, Madison county. Samples mostly in the state of coarse powder, with some friable lumps. Buff colored, with some brown specks in the lumps. Found by going three-quarters of a mile north from Waco, then an eighth of a mile east, and finally an eighth of a mile south, past a cabin.

Geological position: Irvine bed. Collected by A. F. Foerste, 1904.

Analysis; sample air-dried:

Moisture	1.52
Ignition (combined water and volatile matter)	3.56
Silica	81.54
Alumina	9.36
Ferric oxide	1.17
Lime	.10
Magnesia	.39
Potash	.56
Soda	.29
Titanium dioxide	1.25
Sulphur trioxide	None
Total	99.74

The relatively small percentage of alumina should be noted. The point of incipient fusion of this clay has not been determined.

The following clay was analyzed for Mr. Searcy. It does not differ conspicuously from the stoneware clays previously cited. It probably belongs to the upper part of the Irvine formation, as far as may be determined from the analysis. No careful study was made of its position in the geological scale.

2616.—Alluvial clay, Waco, Madison county, Ky.

Geological position: Alluvial clay. One-fourth mile south of Waco, and then one and one-eighth miles east, south of the road, on Grinstead farm. Black clay. A. F. Foerste, 1904.

Analysis of air-dried sample:

Moisture	1.72
Ignition (combined water, etc.)	6.38
Silica	65.82
Alumina	18.01
Ferric oxide	2.48
Lime	.22
Magnesia	.77
Potash	2.91
Soda	.46
Titanium dioxide	1.25
Sulphur trioxide	Trace
Total	100.02

The next analysis gives the composition of the ordinary brick and tiling clay used by the Moberly Brick Company, and secured from the immediate vicinity of the plant, west of Moberly station. It contains a much larger percentage of ferric oxide than any clay here discussed, and evidently would not be useful for any other purpose than that for which it now is employed. It is chiefly an alluvial deposit.

2617.—Clay, Moberly, Ky., Madison county.

Geological position: Irvine formation. Chiefly alluvial. Used for brick and tile at the Moberly Brick Co. plant at Moberly.

Analysis, air-dried:

Moisture	1.98
Ignition (combined water, etc.)	4.20
Silica	74.36
Alumina	7.79
Ferric oxide	6.78
Lime	.14
Magnesia	.53
Potash	1.59
Soda	.49
Titanium dioxide	1.25
Sulphates and phosphates	Traces
Total	99.11

The Clay Industries of Madison County.

Only two stoneware potteries at present are in operation, one at Waco, and the other at Bybeetown, or Portwood.

The pottery half a mile east of Waco is known as the D. Zittel & Son pottery. They use the clay from the George McKinney farm, southeast of Waco. The clay bed varies in thickness from four to seven feet. In some parts of the pit the clay rests upon sand. In these cases it is considered better and will stand a little more fire. In other parts of the pit the clay rests upon the Black shale, and then is believed to be less refractory. No reason for this difference can be noticed on examining the clay in the pit.

Albany slip clay mixed with red lead and manganese is used as a glaze. The materials are obtained from the Bower Pottery Company, Louisville, Ky.

The articles made are as follows:

Jugs in 1 quart and ½, 1, 2, 3, 4, and 5 gallon sizes.

Jars in 1 quart and ½, 1, 2, 3, 4, 5, 6, 8, and 10 gallon sizes.

Fruit jugs, put up with lid so that they can be sealed. Used chiefly for keeping sorghum. Put up in 2, 3, 4, and 5 gallon sizes.

Fruit jars, with lid, in 1 quart and in ½ and 1 gallon sizes. Used chiefly for fruit jams.

Pitchers, in 1 quart and ½, 1, and 2 gallon sizes.

Churns, in 2, 3, 4, 5, and 6 gallon sizes. Supplied with lid.

Milk pans, in ½, 1, and 2 gallon sizes.

Chambers, in ½ and 1 gallon sizes.

Flower pots, in 2, 3, 4, 5, 6, 7, 8, 10, 12, and 14 inch sizes.

The following analysis indicates the chemical composition of the Albany slip clay:

Free silica or sand	38.58
Combined silica	17.02
Alumina	14.80
Ferric oxide	5.85
Manganic oxide	.14
Lime	5.70
Magnesia	2.48
Potash	3.23
Soda	1.07
Phosphoric acid	.15
Water	5.18
Moisture and carbonic acid	4.94
Total	99.14

This clay not only fuses at a low temperature, but also produces a glaze of uniform color, and one which does not crack. Its fusibility may be lowered by the admixture of various metal compounds, as indicated in the following recipe:

Albany slip clay	63.30 to 70	parts.
White lead	25.30 to 17	"
Flint	6.30 to 7	"
Oxide of iron	.72 to .79	"
Oxide of manganese	.56 to .61	"
Chromate of lead	1.27 to 1.40	"
Chromate of iron	.67 to .73	"
Oxide of zinc	1.88 to 2.07	"

At Bybeetown, or Portwood, is located the pottery of J. E. Cornelison & Son. The clay is obtained on the road from Waco to Cobb Ferry, about a mile and a half east of the junction of this road with the road from Waco to Bybeetown. The pit is located northwest of the road corners, at which the road across Falling Brook joins the road from Waco to Cobb Ferry. The thickness of the clay bed in the clay pit averages about five feet. The clay overlies the Black shale. The clay is brought to the shop and put in a ring pit. This ring pit usually consists of a circular tub, between twenty-five and thirty feet in diameter, three feet deep, and lined with boards. In this revolves an iron wheel about six feet in diameter, and so geared that it travels from the center of the tub to its sides and then back again toward the center. This breaks up the clay thoroughly and tempers the clay in about six hours. This tempering is called pugging. The power used at the Bybeetown pottery is a single horse. The clay is taken from the pug tub to the cellar and there kept moist for further use.

The objects manufactured are chiefly jars, jugs and churns, in the following sizes:

Jars, 1 quart, ½, 1, 2, 3, 4, 5, 6, 8, 11 gallons.
Jugs, 1 quart, ½, 1, 2, 3, 4, 5, 6, 8, 10 gallons.
Churns, 2, 3, 4, 5, 6, 8 gallons.

The glaze used is a slip clay mixed with red lead and manganese. This is all stirred together, the slip clay being strained before mixing. The pottery is dipped into the mixture and dried before going to the kiln. The kiln used is a down-draft kiln, and coal is used as a fuel. The kiln is heated up slowly for about twenty-four hours and then raised to a white heat for twenty-four hours. A peep-hole is left to enable the operator to examine the interior of the kiln, and the state of firing is determined chiefly by the color of the ware, although test pieces also are used. Whenever the glaze is good on these test pieces the burning is considered sufficient. Then the kiln is allowed to cool for fifty hours. No Seger cones are used.

In addition to pottery, 4, 6, and 8 inch tiling also is manufactured.

At Searcy station, about a mile southeast of Moberly, the Lexington Tile Roof Company is situated. Here the Waco shingle tile is manufactured.

The chief clay used for this purpose is obtained directly north of the factory. At the pit about half a foot of soil is stripped off at the top, and the underlying clay layer, five feet thick, is taken out. This clay rests on the Black shale. For the manufacture of drain tile, brick, and shingles, the clay is dug, removed to the soak pit, and left over night. The next day the clay is shovelled into the disintegrator, where any stones present in the clay are crushed until the fragments are reduced to a diameter of one sixteenth of an inch or less. From the disintegrator the clay is carried along a belt to the tile mill. Here the clay is pushed out of the tile mill, through the dies, where the proper thickness and width is given to the stream of clay which issues forth. From the tile mill the issuing stream of clay is carried forward by the machine to the cut-off table, where the clay, which already has the proper width and thickness, is cut off into the desired lengths. From the cut-off table the blanks or plates of clay, the future shingles, are carried forward and picked off by boys, who haul them to the shingle press.

Up to this point the manufacture of shingle tiles does not differ in any respect from the manufacture of bricks and drain tiling as carried on at the same factory, except that in each case a different die is used in order to give a different form to the stream of clay issuing from the die, and in each case the wires on the cut-off table are set at different points, so that the length appropriate to the particular object to be manufactured will be cut off. For the manufacture of shingle tiles the clay is heaped up usually about two days, moistened and covered with oil cloth, before it is run through the disintegrator, in order to become evenly moist.

From the cut-off table the clay plates are taken to the press, where they are pressed into shingles. In this machine the upper die is stationary and there are three lower dies, all of which are movable, only one die being used at a time. One of the clay plates is inserted into the machine and pressed. The lower die with the pressed shingle on it is then lifted up. A pallet or small board slightly larger than the shingle is placed on the shingle. Then die, shingle and pallet together are turned over and the die lifted off, the pressed shingle remaining on the pallet. In the meantime another clay plate has been inserted in the machine and pressed into the shape of a shingle, and is

ready to be taken out and placed on a pallet. The shingles, still resting on the pallet, are carried off to the drying shed. The capacity of such a press is 4,000 shingles in one day of ten hours, ten men being employed in various ways.

The shingles are allowed to dry on the pallets for periods varying from two to five days, depending upon the weather. They are then skinned or trimmed. Trimming consists in rubbing off the rough edges of the clay shingles with the back of a coarse knife. Then the shingles are stacked up and taken to the kiln. Here they are set up on edge, eight shingles in each set, with fire-bricks between the sets. These fire-bricks are a little higher than the shingles and so take the weight of the upper tiers of shingles from the tiers stacked up below. The fire-clay used is secured on the Adams farm, as is also some of the clay which enters into the clay mixture used for the manufacture of the shingles.

The kiln used is a down-draft kiln. The shingles are heated for twenty-four hours, the fresh steam or water-smoke being let out at the top. No great heat is used during this time, the object being merely to drive off the water still present in the shingles. Then the heat is raised gradually for forty-eight hours until the shingles become white hot. Then the ovens are closed down, firing ceases, the fire-doors are cemented shut with clay, and for three days the kiln is allowed to cool slowly. It takes a day and a half to empty the kiln and another day and a half to fill the same again.

Three men can fill the soak-pit so as to supply enough clay for fifty squares per day. A square is equivalent to 100 square feet of roof surface, which in the present instance requires the use of 260 shingles. Fifty squares, therefore, would in this case be equivalent to $50 \times 260 = 13,000$ shingles. Two men are needed at the disintegrator. One man is needed at the mill and to take care of the cut-off table. Two men serve as off-bearers, who wheel off the clay plates or blanks to which reference has been made in the preceding lines. One man works the lever at the press, one feeds the press, one dumps the pressed shingle onto the pallet, and one man, the off-bearer, hauls the shingles to the drying room. At the drying room one man is kept busy as a skinner or trimmer. Two off-bearers are needed to fill the kiln, and one man sets up or stacks the shingles in the kiln. Two men are kept constantly employed in firing the

kiln, one serving as the day man, the other as the night man. The men firing the kiln are paid $1.50 per day, and all others are paid $1.00 per day. The man firing the kiln for this wage is given the higher sum of money because he is regarded as an expert. Similar wages are given for similar work at the potteries already mentioned.

The weight of a square of shingles, or of 260 shingles is about 650 pounds. The exposed surface of the shingles is 9.5 by 6 inches. In the process of burning the clay shrinks five-eighths of an inch to the foot and allowance must be made for this in constructing the die. No Seger cones are used in firing the kiln, the temperature being determined approximately by looking at the color of the brick through peep-holes left for this purpose on each side of the door in the front walls of the kiln. Shingles have been made at this factory for about two years. One of the churches at Irvine, in Estill county, is covered with this roofing tile. The shingles seem to be defective, owing to under-burning, and for this reason the use of Seger cones is recommended. They also have a tendency to open up irregular cracks on burning, and hence tests as to the proper mixtures to be employed should be made, but there is no reason why eventually, with greater experience, the manufacture of roofing tiles should not prove a success.

For purposes of comparison with clays from other localities, the following analyses are given. The clay from Vigo county, Indiana, was used formerly for roofing tile, but cracked in burning. The clay from Prospect Hill, in St. Louis county, Missouri, is used both for brick and for roofing tile. The clay (Chemung shale) from Alfred Center, in Alleghany county, New York, produces an exceptionally good quality of roofing shingle.

	Indiana, Vigo County	Missouri, Prospect Hill	New York, Alfred Center
Silica	73.20	60.70	53.20
Alumina	13.38	18.22	23.25
Ferric oxide	2.19	7.58	10.90
Lime	.97	2.68	1.01
Magnesia	1.01	Trace	.62
Soda and potash	....	3.67	2.70

Since roofing tiles or shingles are to be used in order to shed water, their degree of porosity or permeability to water is of

the highest importance. The value of roofing shingles may be tested as follows: Heat the shingle to be tested to a temperature of 212 degrees F., then place on it a tin tube whose diameter is five inches and whose height is eight inches. This should be fastened to the tile by means of wax applied to the outside of the tube. Fill the tube with water up to a level of four inches above the tile, and keep the water at this level by adding a few teaspoonfuls at a time until drops begin to appear on the under side of the tile or shingle. If these drops make their appearance in less than six hours, the roofing tile should be rejected. Tile burned to a higher degree of vitrification is, of course, more impervious to water.

In addition to the roofing tile or shingle, the Lexington Tile Roof Company manufactures also paving brick, eight and three quarters of an inch wide and long, and therefore having a hypotheneuse or diameter from corner to corner of one foot. The thickness of these bricks is two inches. They are intended for paths in gardens, sidewalks in villages, and the like. They are placed with their greater diameters parallel to the length of the walk, and the gaps thus left at the side of the walk are filled in with half bricks which have a triangular shape, fit in snugly, and are supplied in proper quantity with every order.

In addition to the paving brick, drainage tiling and common brick are manufactured. Several tests of different clays from the Waco area, made by the Boyd Company, of Chicago, at the request of the Lexington Tile Roof Company, have demonstrated that a fine grade of pressed bricks can be manufactured from the different clays. These vary in color from a very light yellow to a distinct red. By a mixture of clays they secured a mottled brick giving a very pleasing effect. It is evident that the possibilities of these clays have by no means been exhausted. When the dams now under construction along the Kentucky river are completed, the question of cheap transportation from the eastern part of the Waco area should be considered solved.

Directly west of Moberly station is the plant of the Moberly Tiling Manufacturing Company. This is owned chiefly by William Tate. The clay is obtained at the factory. The layer is three feet thick and occurs immediately over black shale. Three or four inches of soil are stripped off at the top. They use the Little Warder press, made at Frankfort, Ind., by the Wallace

Manufacturing Company. This turns out 5,000 tiles or 2,000 bricks per day. The cut-off table used is the Euring automatic clay cutter, manufactured by the I. D. Fate Company, at Plymouth, O. The tile truck wagon was made by the Arnold-Creager Company, at New London, O. The power for the press and cutter is supplied by a 30 horse-power engine. It requires more power to make the smaller sizes of tiling, four to six inches in diameter, than those of larger sizes. Labor is paid at the rate of $1.00 per day, or 10 cents per hour.

THE BEREA COLLEGE BRICK COMPANY.

The brick-yard run by Berea College for its own use and for the employment of some of the college students is situated about a mile north of town. The clay is obtained from a pit situated northeast of the brick-yard. About three inches of soil are removed, and the underlying clay has a thickness of about three and a half or four feet. It overlies Black shale. A narrow track with cars is used to haul the clay from the pit to the plant, and then, by means of a cable run by steam, up an incline to the second floor of the building, where the bricks are made. At the top of the incline the clay is dumped from the car onto a platform, and then shovelled into the disintegrator. This consists of two large steel rolls, between which the clay passes. Any pebbles present in the clay are ground to small fragments. Water is added to the clay as it reaches these rolls in the disintegrator. From the disintegrator the clay drops into the pug mill. Here revolving blades mix the clay, and if necessary more water is added. In addition to mixing the clay, the blades push the clay forward into the brick mill. This is the Grand Automatic Brick Maker, manufactured by Jonathan Creagers' Sons Company, at Cincinnati, O.

The blades in the brick mill push the clay down into the arms of the brick mill, and these arms push the clay sidewise under the press. Here the press pushes the clay into the mold. Nine molds are used when the machine is in operation. Six bricks are made at a time in each mold. In front of the machine one man receives the mold and bumps it to the right and left so as to loosen the clay brick in the mold. Another man picks up the mold and places it on the turn-table, which is a sort of

revolving wheel. The open side of the mold is placed against a pallet board and the mold is dumped, leaving the brick on the pallet board. Then the mold is put in the sander. The sander in use is made by the Wellington Machine Company, at Wellington, O. In the sander the mold is pushed through the sand, and on the other side another man picks up the mold and places it once more in the machine. In the meantime the other molds have been in use. The sand is shipped here from Cincinnati.

Nine pallet boards, with six bricks on each, are loaded on a truck and then are wheeled to the racks. Here they are taken off by a man and are put on the racks to dry. Between six to nine days are necessary for this purpose. The racks at the pallet yard have a capacity of 120,000 bricks. From the pallet yard the bricks are taken to the kiln. Three kilns are in use, one up-draft Morrison clamp kiln and two common up-draft kilns. The capacity of these kilns is 225,000, 200,000 and 200,000 bricks. The bricks are first fired for about four or five days to drive off the steam, usually called water smoke. After this has been driven off, the escape of the heat is cut off, the fires are increased, and in three or four days the brick comes to a red heat, and to a white heat in three and a half or four days additional. After this, all access of air is cut off, and it requires eight days for the kiln to cool.

The capacity of the yard when worked to its fullest extent is 2,000,000 bricks a year. It has been in operation about four years. The machinery for tile-making has been secured. Prof. S. C. Mason, at Berea, the Professor of Agriculture and Geology, is especially interested in this plant. Aside from its usefulness to the college, it is of great service to the students, who here get a practical knowledge of brick-making, which, with modifications, they can directly apply in the mountain districts from which so many come, doing by hand, of course, many of the things which here are made by machinery.

Water Horizons.

The Devonian limestone is one of the chief water-bearing strata of east central Kentucky. Numerous fine springs issue from its horizon, and some of these have a wide reputation. One of these is the Buffalo spring, a quarter of a mile west of Stanford, along the pike to Hustonville. Another is situated about three and a half miles west of Crab Orchard, along the county road running east and west about a mile south of the railroad, east of the home of George Boone. Another spring is located about three miles southwest of Crab Orchard, near the head-waters of Cedar creek, north of the road leading to Chapel Gap (locality 17 CO-NE). The Moore spring, a mile and a third northeast of Waco, near the home of Tom Curtis, is one of the best known in that area. The Spout spring, four miles south-west of Clay City, is known for many miles. The spring south-east of the Oil springs hotel, about a mile northeast of Indian Fields, issues from the same horizon. These are only a few of many springs which could be mentioned, and which, collectively, demonstrate that the Devonian limestone is an important water-bearing stratum. This importance it does not owe to its thickness, since the Devonian limestone in most of this region does not exceed eighteen feet, and at many localities springs issue from this limestone where its thickness is less than six feet. But the overlying Devonian black shales are so abundantly traversed, at many localities, by minute cracks, that the ground waters percolating through their mass are enabled to reach the Devonian limestone horizon in sufficient quantities to feed numerous springs.

Over by far the greater part of east-central Kentucky, the Devonian limestones are underlaid by considerable quantities of Silurian clays, the most important of which belong to the Alger formation, but the Plum creek clay also is of importance. These clays soften up readily in the presence of abundant ground waters, and form a rather impermeable mass, arresting further downward progress. The slowly percolating ground waters accumulate above the Silurian clays, until they find an exit laterally as springs. The permeability of the Devonian limestones, no doubt, greatly assists in the ready egress of this water. Moreover, the numerous joints and vertical cracks, gradually widen-

ing under the influence of the slightly carbonaceous waters, usually provide channels for the ready exit of springs. The chief service of the Devonian limestone is the providing of a reservoir for the accumulation of the downward percolating ground water, and the providing of channels for its ready outflow.

These springs, at the horizon of the Devonian limestone, are most numerous where the overlying Black slates are not deeply covered by the soft Linietta clays, forming the base of the Waverly series. The latter act as a barrier, retarding the ready downward passage of percolating ground waters, thus preventing easy access to the Black shales and Devonian limetone beneath. The base of the Waverly series, therefore, is not a good water-bearing horizon in east central Kentucky.

For a somewhat similar reason, the Clinton, or Brassfield, limestone is not a reliable water-bearing horizon in this part of the State. Where it is thickly covered by the Plum creek, and especially by the Alger clays, the ground waters are held back and do not accumulate readily at this horizon. Although many springs issue at this horizon, they usually are of moderate size, and they often go dry in summer. This does not suggest the presence of important accumulations of water within the ground, at this horizon, and very little hope may be offered to those who may desire to secure a permanent and abundant water supply at this horizon in this part of the State, while the likelihood of striking an abundance of good water is much greater at the level of the Devonian limestones.

The Richmond formation, in by far the greater part of east central Kentucky, is an argillaceous deposit, often clayey at the top, with comparatively little limestone at any level, though often containing layers of indurated argillaceous rocks. As a matter of fact, few springs issue from Richmond strata in this part of the State. More frequently, the areas of outcrop of Richmond strata are marked by comparatively barren or bald spots, giving rise to such names as "Bald Hills." These names indicate that the Richmond is not a great water-bearing horizon, and that wells reaching the Richmond strata, without having found water, must be continued for at least 200 feet before the chances for a reliable water supply become much better.

The upper horizons of the Maysville division of the Cincinnatian series of rocks, on the contrary, contain much limestone,

traversed by numerous crevices, and probably fairly permeable even where not cracked. At this horizon springs become numerous again, and the great thickness of the Maysville division affords the opportunity for many springs, at numerous localities, and at very different elevations.

There are no porous sandstones, in that part of east central Kentucky here under investigation, within reach of the well driller, and therefore this, the best medium, for the accumulation of ground waters, is absent. But in the absence of sandstones, the Devonian limestone is a valuable water-bearing stratum, and the Maysville limestones offer even a greater supply, while the Clinton, or Brassfield, limestone is uncertain, and the Silurian clays and the Richmond argillaceous strata offer no prospect.

Springs frequently issue from the Black shales, and some of these offer water which is very palatable, but, as has already been shown in that part of the report which deals on mineral springs, in the presence of iron sulphide, chemical reactions often take place which impregnate the waters with various kinds of salts, which may be very valuable for medicinal purposes, but which can hardly be recommended as parts of a steady diet. The quantity of these salts in solution depends, in part, considerably upon the rate of outflow. Where the streams issuing at the springs are at all rapid, the quantity of salt in solution usually is small. Where the rate of outflow is small, the quantity of material in solution often is great. It is evident that the rate at which the chemical changes producing these salts is taking place is too small to permit of the abundant impregnation of considerable quantities of ground water. Where the ground waters flow rapidly, the streams at their exits from the springs are relatively free from salts, at least in the great majority of cases.

The slow rate of percolation of ground waters through the Silurian clays readily accounts for the frequency with which wells sunk into these clays become impregnated with salts. In fact, in former days, these wells were sunk in the Alger clays for the express purpose of securing the brines for the manufacture of the Crab Orchard salts. Of course, natural evaporation was utilized to intensify the salinity of these brines, but the frequency with which the term "lick" is used in this part

of Kentucky demonstrates the fact that Nature herself furnished many natural brines at some localities.

Oil Horizons.

The same conditions which tended to make the Devonian limestone, in many parts of east central Kentucky, a great water-bearing stratum, have locally favored its acting as a reservoir for oil. Oil is lighter than water and tends to rise. Any oil which once reaches the level of the Devonian limestone is likely to be held back by the Linietta clay, at the base of the Waverly, if not by the Black shale, immediately overlying the Devonian limestone. At some localities in the northeastern part of the area here under investigation, this service would be performed very well also by the mass of greenish clays (Olentangy shale ?), often six to eight feet thick, immediately underlying the Black shales. Here, again, the Devonian limestone, on account of its porosity acts as a reservoir. In quarrying this rock, cavities with small quantities of crude petroleum are not infrequent.

The source of this petroleum is a subject of considerable interest to the speculative geologist. The Devonian Black shales are known to be bituminous. In early days, oil was distilled from them, and when thrown into the fire, they undergo a sort of slow combustion, which, frequently, has led the observer to believe that a little further judicious search would lead to the discovery of a new coal field. When those Devonian shales are tilted, the more liquid bituminous material might slowly rise toward the crest of the incline, and, if held back by suitable impervious layers, might accumulate there. A considerable accumulation of oil, in that case, would not mean that the Black shales in general were heavily charged with oil, but that oil has gradually collected from over a very wide territory into some narrow space or pocket. This region of collection would be most pronounced along the most porous strata, where suitably covered by impervious layers.

It is the common opinion of geologists, however, that the general distribution of oil in the earth does not warrant the belief that all accumulations of oil have originated from such

obvious sources as bituminous shales and coals, owing their bitumen to natural chemical changes of the remains of plant life, formerly inclosed within them. Some have sought for the origin of oil in the chemical changes resulting from the decay of animal life, while, recently, it has been suggested that considerable quantities of oil may have had an entirely inorganic origin. The opinion is gaining ground, from the enormous quantities of carbon dioxide given off from volcanic vents, that various metals known near the surface of the earth chiefly as oxides and sulphides, might occur, deep within the interior of the earth, as carbides, and later supply the carbon for mineral oils.

Whatever the truth may be, the thick mass of Silurian clays should be an effective barrier to the rise of oils from greater depths, and, in that case, the presence of considerable quantities of oil in the Devonian limestones should be due to local, rather than to general, conditions. Evidently, faults, if of sufficient throw, might occasionally enable oils to ascend through strata ordinarily impervious.

Oils are found in the Devonian limestones in the Ragland field, in the southeastern part of Bath county, and in the area east of Irvine, in Estill county. Gas is found at the same horizon in Menefee county. (The Oil and Gas Sands of Kentucky, by J. B. Hoeing, Bulletin No. 1, Kentucky Geological Survey.) It is probable that the oil and gas struck at the Caney creek well, in Morgan county, came from approximately the same horizon; not necessarily the Devonian limestone, but from limestone immediately beneath the Devonian Black shale and above the great mass of Silurian clays.* If the very black shale at the depth of 1,028 to 1,035 feet is the Sunbury shale, then the combined thicknesses of the underlying Berea grit and Bedford shale should greatly exceed fifty-two feet, so that the estimate of 283 feet for the Black shale must include, at the top, a considerable quantity of the Linietta shale, at the base of the Waverly, corresponding, approximately, to the Bedford shale of Ohio. The soft blue shale immediately beneath the Black shale section, to which a thickness of thirty feet is assigned in the section, may correspond to the clay at the base of this Black shale in Bath county, possibly corresponding to the Olentangy

*See foot note on following page.—C. J. N.

shale of Ohio. At any rate, observations farther west suggest an increase, rather than a decrease, in the thickness of the Silurian clay section toward Morgan county, and these clays, therefore, are more likely to be 150 feet than thirty feet thick in Morgan county. If that be the case, the sandy limestone of the Caney creek well, in which oil and gas were found, may represent the limestones immediately beneath the Devonian Black shale in Lewis county. This would place their elevation among the Silurian limestones above the great mass of Silurian clays, rather than below, in the Clinton. This attempt to unravel the geology of a district from imperfect well records is largely guess work, but, whatever the truth may be in the case of the well in Morgan county, it is certain that elsewhere in that part of east central Kentucky here under investigation, the Clinton or Brassfield bed is not a source of oil or gas in commercial quantities, although little cavities, one or two inches in diameter, filled with black oil, are common at many localities, especially near the top of the Brassfield limestone, and in the Whitfieldella layer.*

*It is understood that Professor Foerste's remarks on oil and gas horizons are only tentative, and that they refer only to such observations as he had opportunity to make in the area traversed by him. As stated by him, the Silurian clays should act as a barrier to the upward passage of oils, but, of course, they can so act only when they are present, and over a large part of Eastern Kentucky they are entirely absent. It is not only in the Ragland field, and in the area east of Irvine, that oil is found in the Devonian limestone. Oil or gas is found, in larger or smaller quantities, in the Devonian (Corniferous) limestone wherever the latter is drilled through, unless the drilling is done far enough down a slope for salt water to occupy the horizon. The limestone is very often petroliferous on outcrop. It is important that there shall be no misunderstanding on this point, and that conclusions presented in the bulletin on oil and gas horizons shall not be discredited without ample evidence to support the criticism. The questions raised by Professor Foerste were, therefore, submitted to Mr. J. B. Hoeing, whose extended observations made in the especial study of our oil and gas horizons (fortified by a very large mass of data gathered before and since the publication of his Bulletin on Oil and Gas Sands of Kentucky), together with his intimate association with the drilling of the Caney creek well, in Morgan county, referred to by Professor Foerste, place him in a favorable position to discuss the subject. Mr. Hoeing says: "In the Caney creek well the Corniferous was struck in its proper place at the base of the Black Shale, and the Clinton was struck under the light shale. This was the case not only in that well, but in adjoining wells. Both formations gave oil and gas. Both give more or less oil or gas wherever struck in Eastern Kentucky, and both have been drilled through repeatedly and in the same wells. They are decidedly different in all their characteristics, and are easily recognized. The formation called Clinton in the Caney creek well is not above the Silurian clays; the drill does not show the latter below this "Clinton" in the Caney creek or in any of the numerous deep wells drilled in the several adjoining counties of that section, but, on the contrary, always shows the light blue shales just above, as in the Caney creek well. These light blue shales are not the shale at the base of the Black Shale, which Professor Foerste identifies as Olentangy. They are entirely different from it in character, are always separated from it by the Corniferous limestone, and the two different shales (Olentangy and Niagara or Silurian) have repeatedly been drilled through in the same well, and in the order and position as indicated above. No observations could be made on the thickness of the Silurian shale to the southeast, except in drilled wells, from the fact that it is everywhere under cover. Records of wells from the Ohio river clear around to Powell county, and east to the Big Sandy river, in connection with its outcrops and exposures on the eastern edge, all show (as mentioned in the Oil Bulletin) that

Clinton Outlier on Axis of Cincinnati Geanticline.

The thickness of the Clinton or Brassfield limestone on the eastern side of the Cincinnati geanticline, between Stanford and Crab Orchard, varies between 11 and 14 feet. On the western side, between Raywick and New Hope, it varies between 14 and 17 feet. Recently an outlier of this limestone, 14½ feet thick, was discovered about half way between the nearest outcrops hitherto known, east and west of the crest of the geanticline. It is located on Scrub Grass creek, a short distance beyond the home of Jim Jackson Edwards, about three miles southwest of Mitchellsburg. Overlying it is a layer of limestone, 1 foot thick, containing the large crinoid beads, *Whitfieldella* and *Stricklandinia triplesiana*. The Devonian limestone is 2½ feet thick. Opposite the home of J. J. Edwards it is 5½ feet thick, and the base is conglomeritic. This is the

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this shale thickens rapidly from its western and southern outcrops in Clark and Powell to a deep trough of the shales in Bath, Menefee, Fleming, Mason, etc., and then thins again, still more rapidly, to the east and southeast and disappears entirely in all records before reaching the Big Sandy, on the east, and is quite thin to the southeast. The shales are not 150 feet in Morgan county (as Professor Foerste supposes); they have been drilled through repeatedly and shown to be from 30 to 40 feet thick. All evidence, obtained from a great number of wells, in addition to that on Caney creek, goes to show that the divisions in the Caney creek well record are correct. It should be borne in mind that the record of this well is not an imperfect one, but that a competent geologist examined each sample as it was bailed out of the well. The existence of the Berea or Sunbury shale in the Caney creek well is doubted by Professor Foerste, because he considers the interval as given between that and the Black Shale too small, and he assumes that the Linietta has been included with the Black Shale. The fact that the interval is less than it is elsewhere does not warrant such assumption, especially in this case, since all of the series, from the Berea shale down through the Berea grit, the Devonian shales and limestones, and the Niagara shales, are thinning rapidly from their exposures on the Ohio river south to the locality in question. The Berea shale and the underlying Berea grit have been followed from their outcrops on the Ohio river, in Lewis county, by outcrops and well records to the south and found to be thinning rapidly in that direction, but undoubtedly present over all that area. As to the Linietta or Bedford shale, it was repeatedly identified in the Oil Bulletin, and it is shown, in its thinned down section, in the Caney creek well as black shale directly above the Devonian Black Shale. This (Bedford) shale is readily recognized and differentiated from the Devonian Black Shale either in outcrop or in well records. The thinning down of the Devonian is well marked, and the outline of the edge of the limestone is approximately drawn on one of the maps accompanying the Oil Bulletin. In the Caney creek section, wells on the north side of the anticline get a few feet of Corniferous limestone, while wells on the south side get none; both sides, however, show Niagara shales in place. The Clinton, as already stated, is oil and gas bearing over a large area. It has never proved, anywhere that I know of, as prolific as the Corniferous, but this does not eliminate the possibility of accumulations in the Clinton on a commercial scale, especially in places where structure is favorable and the Corniferous is cut out. The conclusions arrived at and the divisions drawn in the Oil Bulletin, while not claimed in all cases to be absolutely correct, are based, not on one well record, but on a careful study of a great many records, together with the outcrops of the rocks themselves and of actual samples taken from well drillings; they are believed to be in the main correct." It may be remarked that large, solid samples of limestone identified respectively as Clinton and as Corniferous, which have been obtained from some of the oil wells, are very different in appearance; the oil cavities are quite unlike, and the rocks differ in other important respects.—C. J. N.

locality mentioned by Linney on page 37 of his Report on Nelson County. There is a strong unconformity between the Clinton and Devonian limestone. This outlier is interesting in showing a probable transgression of the Clinton, at least in Central Kentucky, across the area now occupied by the axis of the Cincinnati geanticline.

PART III.

CHARACTERISTIC FOSSILS

OF THE

SILURIAN FORMATIONS

. . OF . .

EAST CENTRAL KENTUCKY.

CHIEFLY FROM THE WACO LIMESTONE HORIZON.

List of Fossils Described on the Following Pages.

The species here described include only a few of the more characteristic forms which, on account of their wide distribution in the field under investigation, will serve to distinguish the more important horizons. A fuller account of the fauna must await a future time.

Characteristic Fossils of the Silurian Formations of East Central Kentucky.

CHIEFLY FROM THE WACO LIMESTONE HORIZON.

MEEKOPORA BASSLERI, N. SP.

Plate 6. figs. 1A, 1B.

Maximum size of zoarium unknown, but the largest fragments indicate a length of at least 150 millimeters. Zoarium forming thin, flat, branching expansions. The thickness of the zoarium varies between half a millimeter and fully two and a half millimeters. The width of by far the greater number of lobes or branches varies between 10 and 15 millimeters, occasionally reaching 22 millimeters at the points of branching. Zoarium bifoliate, celluliferous on both sides, with rather broad noncelluliferous margins. Apertures circular, elliptical, or, more commonly, oblique and more nearly V-shaped, with the peristome much elevated on the posterior or postero-lateral sides, where the elevation forms a regular lunarium, pointed distally. Apertures arranged more or less regularly in quincuncial order, about 9 or 10 in a width of 5 millimeters, measuring along one of the oblique rows, and 8 in the same distance measuring longitudinally. Maculae occur at intervals of about 5 millimeters; they are rather inconspicuous to the unassisted eye, but under a hand lens they appear as well-marked solid spots, 1 to 2 millimeters in diameter, from which the apertures radiate. In one of the specimens figured the branches vary considerably in width. In smaller fragments the branches retain approximately the same width for lengths of 30 millimeters. The larger specimen figured merely happens to be one in which branching occurs at shorter intervals than usual. Zooecia tubular. Apertures oblique; opening directed chiefly distally or toward the median part of the frond; occasionally two or three of the apertures along the posterior border of the maculae are directed obliquely backward. Occasionally the peristome rises around the aperture on all sides, forming a

small rounded elevation with a tiny apical opening. Ovicells not recognized.

Locality and position: The specimens figured were found north of Estill springs, north of Irvine, Kentucky; they occur also east of Panola; half a mile east of Waco; a quarter of a mile south of Indian Fields; a mile southeast of Indian Fields, where the road from Kiddville joins the road from Indian Fields to Clay City; at Tipton Ferry, and at numerous other localities. It is the most characteristic fossil of the Waco limestone horizon, and I take great pleasure in naming it after Mr. Ray S. Bassler, as a slight acknowledgement of the many favors received from his hand. In my studies of the Ordovician areas of Ohio, Indiana and Kentucky, I have received so much assistance from Mr. Bassler and Mr. John M. Nickles that I cheerfully give all credit for the more valuable results to these gentlemen.

Favosites Gothlandica, Lamarck.

Plate 2, figs. 1A, 1B.

Corallum in broad, flat discoid expansions, relatively thin considering their width. Specimens often attaining a width of 30, and occasionally of 50 centimeters. Thickness varying from 20 to 50 millimeters. Base with a concentrically wrinkled epitheca, often absent in weathered specimens. Corallites prismatic, subequal in the same specimen; usually from 4 to 5, occasionally 6 millimeters in width. Tabulæ flat or slightly convex or concave, frequently with marginal crenulations or depressions, about 12 in number, distinctly developed. Tabulæ numerous, varying from 10 to 12 in a length of 5 millimeters. In vertical sections the tabulæ often appear confused and broken, and at times even present an appearance suggesting a coarse vesicular structure, but the actual presence of such a structure could not be definitely determined, and it probably does not occur. The presence of septal spines could not be determined in the specimens at hand. Pores surrounded by a slightly raised rim, difficult to detect in most specimens, either because very rare or because they are not well exposed; occasionally seen in vertical rows.

This variety of *Favosites Gothlandica* (frequently called

Favosites favosa) is remarkable for the thinness of the corallum, considering its width.

Locality and position: Along the road north of Estill Springs, north of Irvine; directly east of Panola, along the road south of the railroad; along the road directly north of Vienna; southeast of the home of J. T. Elkins, 5½ miles south of Indian Fields, along the road to Vienna; along the small stream a quarter of a mile south of Indian Fields; along the road immediately north of Tipton Ferry, 2 miles southwest of Clay City, Kentucky. In the Waco limestone layers, of Silurian age, Figure 1A represents a specimen from Irvine, Kentucky; figure 1B represents the closely arranged tabulæ, but without showing the broken and vesiculose appearance of some specimens.

FAVOSITES HISINGERI-APLATA, N. V.

Plate 2, fig. 2, and Plate 4, fig. 5.

Corallum flat, usually in fragments 50 to 100 millimeters wide and 10 to 15 millimeters thick; occasionally 200 to 300 millimeters wide and 45 millimeters thick. Corallites small, varying from .75 to 1 millimeter in width, usually slightly less than one millimeter; polygonal. Tabulæ at varying distances apart, from 9 to 16 in a length of 5 millimeters, occasionally as few as 5 in this length. Septal spines numerous, sometimes reaching half way to the center of the corallites, but frequently not so well preserved and therefore shorter; pointed and curved upward at the end; arranged in 12 vertical rows. Pores small and apparently few in number. Lower surface of the corallum with an epitheca which is concentrically wrinkled and striated, and radiately marked by narrow grooves distinctly delimiting the corallites. The corallites at the base of the corallum first grow parallel to the epitheca, and then rise vertically toward the surface.

This is probably the same variety as that identified by C. Rominger as *Favosites venusta*, in his work on Fossil Corals, Geological Survey of Michigan, volume 3, 1876, plate 5, figure 3, from Drummond Island, Michigan. *Favosites venusta* is described by Hall as having corallites varying from one twenty-eighth to one twenty-fourth of an inch in diameter, and 12 as-

cending spiniform rays. In our specimens the septal spines either are not well preserved, or are characteristically much shorter and therefore do not appear as long spines strongly curved up at the ends. Moreover, *Favosites venusta* is described as being hemispheric or spheroidal, while our specimens are rather flat and discoidal.

Specimens similar to ours but with slightly wider corallites are figured by William J. Davis in his Kentucky Fossil Corals, plate 8, figures 7, 10.

For the flat variety here described the name *Favosites hisingeri-aplata* is here proposed.

Locality and position: Along the road north of Estill Springs, north of Irvine; south of the railroad, a short distance east of Panola station; a mile southeast of Indian Fields, along a road crossing the railroad, a short distance before joining the road from Indian Fields to Clay City; two miles southwest of Clay City, along the road immediately north of Tipton Ferry. The specimen figured, figure 2 on Plate 2, was obtained at Irvine. The enlargement, figure 5 on plate 4, under a lens, shows traces of the spinules. In the Waco limestone layers of Silurian age.

FAVOSITES DECLINATA, N. SP.

Plate 2, figs. 4A, 4B, and Plate 4, fig. 4.

Corallum small, attaining a width of 70 millimeters and a thickness of 20 millimeters, but most specimens do not exceed a width of 40 millimeters. Lower surface with an epitheca which is strongly wrinkled and striated concentrically, and also marked radially by narrow grooves which limit the boundaries of the corallites where in contact with the epitheca. Corallites, where in contact with the epitheca, practically horizontal; thence rising obliquely toward the upper surface of the corallum; apertures polygonal, more or less oblique. Where the apertures are strongly oblique, the vertical diameter may be as little as .7 millimeter, while the lateral diameter is 2 millimeters, but usually the obliquity is much less and the differences between the diameters less striking. Near the central part of the upper surface of the corallum the corallites are approximately vertical and the obliquity of the apertures is less

evident. Tabulæ present; rather distant, about 4 to 5 in a length of 5 millimeters. In vertical sections the oblique growth of the corallites from the epitheca to the upper surface of the corallum is distinctly shown; the tabulæ usually occupy a position intermediate between the horizontal and one at right angles to the direction of the corallites; tabulæ often convexly curved. Inner walls with numerous granules which in some specimens are very well preserved and in others are less distinct. In some very well preserved specimens the granules are distinctly arranged in transverse and in longitudinal lines, the transverse lines being parallel to the tabulæ. In other specimens only the longitudinal lines, or only the transverse arrangement, is readily distinguished, while in some specimens the arrangement is rather irregular. The number of longitudinal rows varies between 18 and 24. Granules occur also upon the upper side of the tabulæ in some specimens. Corallites subequal, averaging 2 millimeters or a little less in width at the apertures; rarely longitudinally wrinkled, never with distinct longitudinal ridges, as in species of *Alveolites*.

Locality and position: Along the road north of Estill Springs, north of Irvine; east of Panola, along the road south of the railroad; half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine; two miles southwest of Clay City, along the road immediately north of Tipton Ferry. In the Waco limestone layers, of Silurian age. Figures 4A and 4B on plate 2 represent specimens from Irvine, Kentucky. An enlargement is shown in figure 4, plate 4.

Syringolites huronensis, Hinde.

Plate 2, fig. 3, and Plate 4, fig. 2.

Corallum flat, or gently convex, attaining a width of 120 millimeters and a thickness of about 15 millimeters. Lower surface with an epitheca wrinkled and striated concentrically, and marked by flat radiating lines and also by narrow but distinct radiating grooves limiting the boundaries of the basal parts of the corallites. The corallites are horizontal where in contact with the epitheca and then rise vertically toward the upper surface of the corallum. Corallites polygonal, 2.5 millimeters in width. Tabulæ about 10 to 13 in a length of 5 millimeters,

sloping downward toward the center; upper surface of the tabulæ covered by numerous granules irregularly arranged in 12 radiating sets indistinctly defined from each other. In no case are the granules arranged in distinct radiating rows as in the figures given by Nicholson in his Tabulate Corals. This granulated surface may be traced as far as the center of the corallites in well-preserved specimens. Vertical sections, however, show that the tabulæ have a funnel-shaped form, ending at the center in a narrow tube, the tubes of different funnels uniting so as to form a continuous central tube. This tube is crossed by horizontal plates which appear to be more numerous than the tabulæ. It is probably due to these horizontal plates within the tubes of the invaginating funnels that the apertures of the tubes are not readily detected on the upper side of the tabulæ of well-preserved specimens. The lower side of these invaginating funnels usually is well exposed on the lower side of strongly weathered coralla. The tubular basal part often remains on the upper side of strongly weathered specimens as a small, central, sharply elevated tubular wall or ring. The diameter of the continuous funnel varies from .75 to 1 millimeter. In some specimens granules are seen on the inner walls of these tubes, and granules appear also on the inner walls of the corallites, irregularly arranged.

Judging from the description of *Syringolites huronensis* given by Lawrence M. Lambe, in his Revision of Canadian Palæozoic Corals, part 1, page 45, our specimens are identical with the type specimens from Manitouaning, Grand Manitoulin Island, in Lake Huron. He states that the septa consist of small spiniform bodies present in large numbers and apparently without definite order on the inner walls of the corallites, and that spines similar to these in size and shape are equally abundant on the upper surface of the tabulæ and extend into the tube. If instead of spines the word granules be substituted the description would fit our specimens very well.

Syringolites huronensis finds a near relative in *Roemeria kunthiana*, Lindstroem, from the Silurian of Gotland, Sweden, from which it differs chiefly in the greater regularity of the funnels, which never are absent in the American species, and in the radiate arrangement of the septal granules along the flat bottom of the calyces.

Locality and position: Two miles southwest of Clay City, along the road immediately north of Tipton Ferry; a mile southeast of Indian Fields, east of the home of Brownlow Bruner, where the road from Kiddville joins the road from Indian Fields to Clay City; half a mile east of Waco, where the road to Cobb Ferry starts off from the pike to Irvine; along the road north of Estill Springs, north of Irvine. In the Waco limestone layers, of Silurian age. Figure 3 on plate 2 represents a specimen from Tipton Ferry. Figure 2 on plate 4 is an enlargement of the same. The radial grouping of the septal granules is shown indistinctly.

HELIOLITES SPONGIOSA N. SP.

Plate 3, fig. 3; Plate 4, fig. 6; and Plate 5, fig. 5.

Corallum apparently in the form of a flat discoidal mass, of which only a part is preserved in the specimen described. Corallites vertical in this specimen, but the lower, epithecal part of the corallum is not present. Corallites averaging about 1.5 mm. in diameter, and about 2 mm. apart. The spaces between the corallites are occupied by numerous polygonal tubules, parallel to the corallites. As seen on the upper surface of the corallum, the tubules are very irregular in size and arrangement, producing a sort of spongiose appearance, which is regarded as the distinguishing characteristic of this species. Some of the tubules are fully half a millimeter in diameter at the surface, while others are scarcely a third or even a fourth as wide, and have, therefore, scarcely a ninth of the cross-sectional area. The horizontal tabulæ in the corallites are rather regular in disposition, and number about 15 in a length of 5 mm., while the tabulæ in the tubules number about 22 to 25 in the same distance. As in all other species, however, there is a considerable variation in the distance between the tabulæ. The edges of the calyces are not raised above the general surface of the corallum; and both large and small apertures of tubules are in contact with these edges, the calyces not being surrounded by a narrow radiate border. No septa were detected in the corallites, nor could the presence of septal spines be determined by an examination of the exposed parts of the corallite tubes, although the possibility of their appearing in cross-sections of the corallum is not altogether excluded.

Distinguished from other species of *Heliolites*, as far as known, by the spongiose appearance of the upper surface of the corallum, the absence of septa within the corallites, and, apparently, also by the absence of a distinct exsert marginal rim where the corallites reach the surface.

Locality and position: Found along the road north of Estill Springs, north of Irvine, Kentucky, in the Waco limestone layers, of Silurian age. The enlargement on plate 4 in figure 6 shows distinctly the irregular size and arrangement of the interstitial tubules.

Heliolites sp.

Plate 3, fig. 4.

Corallum in form of a discoidal mass, with a concentrically wrinkled epitheca beneath. Corallites scarcely one millimeter in diameter, from one to nearly two millimeters apart. The spaces between the corallites occupied by polygonal tubules, about six or six and a half in a width of two millimeters. Tubules approximately of equal size. Corallites apparently with short septal spines along the inner walls, extending toward the center along the horizontal tabulæ, but not sufficiently preserved for accurate study. The surface of the specimen is weathered; in this condition it shows no evidence of the margins of the corallites having been raised slightly above the general surface of the corallum, nor of a central elevation in the corallites (due to the convergence of upward directed septal spinules) as in the case of *Heliolites interstincta*. Probably a distinct species, characterized by its discoid growth, small corallites, and relatively large tubules.

Locality and position: Found along the road north of Estill Springs, north of Irvine, Kentucky, in the Waco limestone layers, of Silurian age.

Heliolites subtubulata (?), McCoy.

Plate 3, figs. 5A, 5B.

Corallum flat, 60 or more millimeters wide and 10 millimeters thick in the specimens at hand; probably attaining a much larger size. Lower surface with a concentrically wrinkled

epitheca. Corallites circular, averaging .75 millimeters in diameter, and usually from 1.5 to 2 millimeters distant from each other. The interstitial tubules are polygonal; at the surface of the corallum about 8 or 9, sometimes 10, apertures are seen in a width of 2 millimeters. Horizontal tabulæ in the corallites number about 6 to 8 in a length of 2 millimeters; 9 to 11 occur in the interstitial tubules in a length of 2 millimeters. The margins of the calices rise slightly above the general surface of the corallum. Septal ridges or spinules, if present, not distinctly recognized. In the figure of *Heliolites subtubulata*, published by C. Rominger, in volume 3, of the Geological Survey of Michigan, in 1876 (plate 1, figure 4), the tubules are arranged in parallel rows, best shown by the figure of the specimen from Drummond Island, Michigan. In our specimens, represented by figure 5B, the arrangement is much less regular, although in some specimens the tubules are arranged in approximately parallel lines for short distances. It is not known whether the parallel arrangement of the tubules is constant in the Drummond Island specimens.

Usually identified with *Heliolites subtubulata*, McCoy, from the Wenlock limestone of England, but differing from the type specimens in the smaller size of the corallites, the greater distance between them, and the absence of any unusual thickness in the case of their walls. Provisionally, our specimens may be known as *Heliolites subtubulata-distans*.

In a second group of specimens presenting about the same features as those just described, the coralla increase in height rather than in width, traces of an epithecal structure being shown at different levels on the steep sides. In the specimen figured here, figure 5A, the corallum attains a width of 20 millimeters and a height of 17 millimeters. The tubules are arranged in a rather irregular manner, about 8 or 9 occupy a width of 2 millimeters. Septal spinules short, not distinctly recognized. Provisionally these specimens may be known as *Heliolites subtubulata-nucella*.

Locality and position: The larger, flat and relatively thin specimens (*Heliolites subtubulata-distans*) were found half a mile east of Waco, and along the road north of Estill Springs, near Irvine, Kentucky. The small and relatively thick specimens (*Heliolites subtubulata-nucella*) were found north of

Estill Springs. All occur in the Waco limestone layers, in the Silurian.

LYELLIA EMINULA, N. SP.

Plate 3, fig. 6; Plate 4, fig. 3.

Corallum with upper surface flat or moderately convex; in the type specimen, expanding from a narrower base so as to reach a width of 40 and a height of at least 25 millimeters. Corallites varying in width from 1.2 to 1.5 millimeters, and from .75 to almost 2 millimeters apart. The edges of the corallites are raised slightly above the general surface of the corallum. Septa twelve in number, consisting of carinæ bearing stout spines, which in the specimens examined appear to be short but conspicuous. Interstitial spaces filled with vesicular structure consisting of convex plates resting on each other in such a manner as to form somewhat lenticular cavities varying in width from 1 to 2, occasionally 3, millimeters. The type is represented by figure 6 on Plate 3, and figure 3 on Plate 4. The surface of another specimen, not the type, resembles that of *Heliolites*, the intercalicular surface being marked by numerous small pits having polygonal outlines, at first sight suggesting the presence of intercalicular tubules as in *Heliolites*. The pits reappear on layers at different levels; they are separated by raised and fairly sharp borders. About four and a half to five occur in a width of 2 millimeters. A similar structure is revealed by a lens in *Lyellia americana*, figure 1, plate 2, of C. Rominger's Fossil Corals, published in the third volume of the Geological Survey of Michigan, in 1876. The appearance is that of a bryozoan incrusting the surface, but leaving the apertures of the corallites free.

These forms may be regarded as small varieties of Lyellia americana, with corallites of smaller diameter, with shorter septal spines, and smaller vesicular cavities in the interstitial spaces. The edges of the calices do not bear a circle of twelve rounded tubercles, and no rounded tubercles are observed on the intercalicular surfaces. It will be noticed that these statements involve chiefly negations of characteristics seen in well-pre-

served specimens of *Lyellia americana,* or the development of certain of these characteristics on a smaller scale.

Locality and position: Found along the road north of Estill Springs, north of Irvine, Kentucky, in the Waco limestone layers, of Silurian age.

Flat specimens occur, having a width of 65 millimeters, and a height of less than 10 millimeters, with a concentrically wrinkled epitheca. The corallites are often 3, and even 4, millimeters apart. The septal ridges or spinules are much less prominent; the vesicular cavities are smaller, and the intercellular pits on the intercalicular surface are always well preserved. This may be a distinct species. It is well represented by figure 1 on plate 4, and by figure 4 on plate 5, both of which are enlargements. It occurs in the Waco limestones, half a mile east of Waco, where the road to Cobb Ferry leaves the Irvine pike.

ZAPHRENTIS INTERTEXTA, N. SP.

Plate 7. figs. 1A, 1B.

Corallum simple, conical, curved. In the specimen showing the interior of the calyx, the distance from the base of the corallum to that part of the exterior of the corallum which is on a level with the twisted center is about 55 millimeters when measured along the convex side, and scarcely 30 millimeters when measured along the concave side; the width of the corallum at this level is 43 millimeters measured transversely, and 37 millimeters measured from front to rear parallel to the septal fossette. In a second specimen, not showing the interior of the calyx, the length from the base of the corallum to the edge of the calyx is 80 millimeters measured along the convex side, and 43 millimeters measured along the concave side of the corallum; the width of the top of the corallum is 35 millimeters measured transversely, and 50 millimeters from front to rear, but the corallum has been compressed laterally. Its original dimensions were probably about 45 millimeters measured transversely, and scarcely 40 millimeters measured from front to rear. Epitheca complete, with longitudinal septal furrows moderately distinct. Septa numbering about 90, alternately long and short; of these the longer septa extend toward the center, uniting, twisting and crossing each other, so as to form a broad, convex, irregularly reticulated mass at the bottom of the calyx, re-

sembling the pseudo-columella of *Streptelasma rusticum-canadensis*. Judging from a comparison of the two specimens here described, the depth of the calyx is about 21 millimeters, in specimens of this size. A distinct septal fossette is present on the convex side of the corallum, extending up the neighboring part of the pseudo-columella. Along that part of the pseudo-columella bordering on the septal fosette, the edges of the primary septa are much less conspicuous.

The species is believed to be closely related to *Zaphrentis Stokesi*, from the Silurian of Drummond Island, in Lake Huron. Compared with the typical forms, our specimens are much less elongated, and widen more rapidly from the base. The number of septa is conspicuously smaller. Moreover, in our specimens, the primary septa not only curve on approaching the center, but they cross each other in an irregular manner. The edges of the septa on the pseudo-columella are much coarser, but this may not be a constant character. Compared with *Zaphrentis umbonata*, Rominger, from the Silurian of Michigan, our specimen has a broader and less prominently elevated pseudo-columella; moreover, this pseudo-columella is not laterally compressed. The larger size, the greater number of septa, and the distinct septal fossette serve to distinguish it from *Streptelasma spongaxis*, Rominger, from the Silurian of Point Detour, Michigan. Our specimen may be only an extreme phase of some species. In the present stage of information, it appears sufficiently different to receive a distinct name.

Locality and position: Along the road north of Estill Springs, north of Irvine, Kentucky; two miles southwest of Clay City, along the road immediately north of Tipton Ferry. In the Waco limestone layers, of Silurian age.

ZAPHRENTIS INTERTEXTA, VARIETIES OR YOUNG.

Plate 7, figs. 5A, 5B, 5C, 5D, 5E.

Associated with the type specimens of *Zaphrentis intertexta* are comparatively numerous smaller specimens having the same general exterior form and appearance, but the twisting and crossing of the primary septa at the center of the calyx is less conspicuous, there is no very distinct convex elevation forming a pseudo-columella, and the edges of the septa are thinner. The

septal fossette is always distinctly developed. Specimens of this type frequently attain a width of 35 millimeters. They are regarded as being merely younger states of *Zaphrentis intertexta*. They occur not uncommonly along the road north of Estill Springs, north of Irvine; east of Panola station, along the road south of the railroad; half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine. In addition to these specimens there are others whose affinities are not so readily determined. Figures 5A and 5B illustrate specimens in which there is no distinct evidence of the interlacing of the inner ends of the septa into a pseudo-columella. On the contrary, the median posterior and anterior septa apparently join so as to form a single continuous septum across the calyx, from front to rear, nearly straight in figure 5A, but distinctly bent into an open sigmoidal curve in the second specimen, of which a lateral view is presented in figure 5B. This median septum is approached, but not crossed, by the other septa, on each side. Where the median septum is straight, in passing across the middle of the calyx, the other septa are nearly straight. Where the median septum is strongly bent, the inner ends of the other septa are more distinctly flexuous on approaching the center of the calyx. A somewhat similar condition is represented by figure 5D, in which, however, there is no continuous medium septum from front to rear, and the number of primary septa does not exceed 36.

Figure 5C illustrates one of the smaller specimens from Irvine, weathered so as to show the whole of the uppermost tabula extending entirely across the corallum. This tabula is nearly flat, bending downward at the margin, and descending much more strongly into the septal fossette. The middle of the fossette is marked by the edge of one of the primary septa. The inner edges of the other septa are moderately flexuous and show faint evidences of interlacing. The number of primary septa is about 35.

Taken by themselves, the specimens represented by figures 5A and 5B, and those represented by 5C, 5D, and 5E apparently form at least two distinct species, but apparently they are connected by numerous intermediate forms. For the first set, provisionally, the name *Zaphrentis intertexta-irvinensis* is suggested, and for the second, *Zaphrentis intertexta-juvenis*. The latter

may be identical with *Zaphrentis bilateralis,* Hall, and not at all closely related to *Zaphrentis intertexta,* but this can not be determined until enough specimens have been collected, at all stages of growth, to be able to identify the young of *intertexta* with confidence.

ZAPHRENTIS CHARAXATA, N. SP.

Plate 7, figs. 4A, 4B, 4C, 4D, 4E.

Corallum small, simple, curved. Length from 15 to 20 millimeters; maximum width about 15 to 18 millimeters; depth of calyx about 6 to 7 millimeters; the greater part of the calyx usually is worn away in the specimens at hand but the base of the calyx with the edges of the septa and the septal fossette frequently are well exposed. Number of primary septa usually between 28 and 33; intermediate between these is an approximately equal number of secondary septa. Primary septa usually strongly thickened on approaching the walls of the calyx, and coalescing there so as to produce the effect of thick-walled coralla. Secondary septa also thickened along the walls of the calyx, but usually seen only along the upper part of the calyx and not extending more than a short distance toward the center. In some specimens the space between the primary and secondary septa is so small that the secondary septa can not be recognized readily; this contributes to the thickened appearance of the walls of the coralla. In a few exceptionally well-preserved specimens the sides of the primary septa were marked by transverse and rather coarse striations. These striations apparently are better developed near the walls of the calyx than near the edges of the septa. Exterior of the corallum marked by rather faint longitudinal grooves which on slightly weathered specimens appear as zig-zag lines dividing the surface into small polygonal facets arranged in more or less quincuncial order. These facets, polygonal or more irregular in outline, are well shown by strongly weathered surfaces and their development probably has some indirect connection with the transverse striations on the septa. No denticulations were seen along the inner edges of the septa. Median septal fossette well developed on the convexly curved side of the corallum. Two of the primary septa bordering on the fossette, one on each side, unite

at the inner end of the fossette so as to form a curve like the rounded end of a horse shoe, against which the other primary septa, coming from all directions, terminate. In most specimens only a single primary septum and the corresponding secondary septa are seen along the farther end of the septal fossette, but in one specimen two primary and three secondary septa were found in this position. The inner ends of the septa on approaching the septal fossette may partially coalesce so as to form a rather irregular but comparatively smooth area. In other cases the edges of the septa may be distinguished as far as the borders of the septal fossette. In a few cases they form a small nodulose area, bordering the inner end of the fossette, suggestive of the nodulose irregularities at the center of the calyx of young specimens of Streptelasma. The distinguishing features of this species, in the area where found, are its small size, distinct median septal fossette, thick walls, and the facetted appearance of the epitheca even in little worn specimens, becoming very distinct in more weathered specimens. Compared with *Streptelasma patula*, described by Rominger from the Silurian of Drummond Island and Point Detour, in Lake Huron, our specimens are more curved, have a more pronounced septal fossette, and smaller primary septa, leaving room for a wider calicular cavity.

Locality and position: All of the specimens figured are from the locality along the road north of Estill Springs, north of Irvine, Kentucky; specimens occur also a short distance east of Panola, along the road south of the railroad. Found in the Waco limestone layers, of Silurian age.

LINDSTROEMIA LINGULIFERA, N. SP.

Plate 5, figs. 2A, 2B, 2C, 2D, 2E, 2F.

Corallum small, simple, curved. Height usually not over 15 millimeters, but sometimes reaching 17 millimeters. Exterior marked by fine longitudinal grooves corresponding in number to the septa within; also with numerous fine, transverse, concentric striæ. Primary septa varying in number from 27 to 33, uniting at the center of the calyx into a vertical, laterally compressed, linguliform columella, or, at least, forming a conspicuous ridge toward which the other septa converge. A median

septal fossette is found on the posterior side of the calyx; in most specimens this fossette is comparatively shallow and indistinct, but usually the primary septum occupying this fossette does not extend quite as far toward the interior of the calyx as the other primary septa. Secondary septa present, but not conspicuous on account of a thick deposit of sclerenchym on the inner walls of the corallum, between the bases of the septa, thus producing the appearance of a thick-walled corallum. This sclerenchym also partly fills in the base of the visceral chamber. Tabulæ few.

This species may be distinguished from *Lindstroemia gainesi*, W. J. Davis, from the Clinton, 12 miles east of Louisville, Kentucky, by the less conspicuous secondary septa, caused by the much thicker deposit of sclerenchym on the inner walls of the corallum. *Lindstroemia wisconsinensis*, Whitfield, from the Racine limestone (Silurian) of Wisconsin, is a much larger species. The type species, *Lindstroemia dalmani*, occurring in the Silurian of Gotland, Sweden, is of intermediate size. The genus is chiefly Silurian, but *Lindstroemia subduplicata* occurs in the Caradoc of Ayrshire, England, near the top of the Ordovician; it apparently is closely related to the Kentuckian forms. The genus appears to have had its origin in very early Ordovician times. At any rate, a rugose coral with a laterally compressed linguliform columella, labelled as coming from the Birdseye and Black river limestone at the Petite Chaudiere rapids, at Ottawa, Canada, occurs in the Museum of the Canadian Geological Survey. This specimen, equal in size to the Kentucky Silurian specimens, here described, is conical, moderately curved, has 30 primary septa, an equal number of secondary septa, a rather indistinct septal fovea, and no readily perceptible deposit of sclerenchym. For this species, here associated with *Petraia profundum*, the name *Lindstroemia whiteavesi* is proposed.

Locality and position: Figures 2A, 2B are from specimens found a short distance east of Panola, along the road south of the railroad. Figures 2C, 2D, 2E, 2F are from specimens found along the road north of Estill Springs north of Irvine. This species occurs also half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine. In the Waco limestones, of Silurian age.

POLYOROPHE RADICULA, N. SP.

Plate 5, figs. 3A-3E.

Corallum resembling in form the specimens identified from Louisville, Kentucky, as *Cyathophyllum radicula by W. J.* Davis (Kentucky Fossil Corals, plate 86, figures 2, 3, 4, 5, published in 1885), but structurally distinct both from that species and from typical forms of *Cyathophyllum radicula* as described by C. Rominger from the Silurian of Drummond Island, Michigan.

Corallum simple, attaining a width of 10 to 12 millimeters and a length of 30 millimeters, usually less. Transversely wrinkled and constricted owing to calicinal rejuvenation; the edges indicating former positions of the calyx frequently are distinctly visible as narrow encircling rings edged on the upper side by the septal denticles, producing an appearance a little like the milled edge of a coin. Growth often only moderately curved or nearly straight, but frequently strongly and irregularly curved or bent. Surface of the epitheca marked by longitudinal lines corresponding to the septa in number. In some specimens minute granules occur along these septal striæ, usually in the form of a single row of rather distant granules along each septal line. In other specimens these granules can not be distinguished. In addition to the coarser markings, fine transverse striæ often are present.

Septa, about 60 to 70 in number, very narrow, extending but a short distance from the walls of the calyx, represented chiefly by vertical series of rather prominent denticles. The broken walls of the corallum occasionally appear rather thick, almost a millimeter in some cases, suggesting the presence of a thick deposit of sclerenchym, on the inner walls of the corallum, beyond which the denticles project. In other specimens these walls do not exceed one-third of a millimeter in thickness. There appears to be no evidence of the presence of dissepiments. Tabulæ rather distant, extending across the entire width of the corallum. Their direction varies from directly transverse to oblique, depending upon the direction of the calicular aperture at the time of their formation. Tabulæ comparatively flat in the specimens at hand, covered on the upper side with more or less distinctly radiating lines of coarse granules

which evidently are continuations of the vertical rows of septal denticulations on the inner walls of the corallum. These granules are present over the entire upper surface of the tabulæ, but their arrangement in rows may be better detected in the more peripheral part as a rule. The lower side of the tabulæ appears to be smooth.

While possessing the generic characteristics of the type species, *Polyorophe glabra*, Lindstroem, from the Silurian of Gotland, Sweden, our specimens present a widely different external appearance. They are much smaller, cylindrical rather than conical, and do not possess the lateral, radiciform outgrowths of the epitheca; moreover, the Kentuckian specimens never show evidences of branching nor are united into colonies. *Aphyllostylus gracillus*, Whiteaves, from the Silurian of Manitoba, possesses the septal denticles along the inner walls of the corallum, but not the more or less radiately arranged granules on the upper sides of the tabulæ.

Locality and position: The specimens represented by figures 3A, 3B and 3E are from along the road north of Estill Springs, north of Irvine, Kentucky; those used for figures 3C and 3D are from half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine; specimens occur also a mile southwest of Indian Fields, where the road from Kiddville joins the road from Indian Fields to Clay City. In the Waco limestone layers, of Silurian age. Figures 3A and 3B are enlargements; owing to the angle at which the views were taken, the specimen represented by these figures appears to be conical, but this is the effect of fore-shortening.

CYATHOPHYLLUM DENSISEPTATUM, N. SP.

Plate 6, figs. 2A-2F.

Corallum simple, of moderate size, curved, attaining a length of 75 millimeters measured along the convex side, and a width of 30 millimeters at the top of the corallum. Epitheca very thin, usually removed by weathering; marked by low, flat longitudinal and rather inconspicuous rugæ corresponding in number to the septa within, also by numerous fine transverse striations, and coarser growth lines and wrinkles. Calyx rather shallow, specimens 28 millimeters wide having calices with a depth of 8 or 9

millimeters. Septa about 90 in full grown specimens, only the primary septa reaching the center where the ends are more or less twisted and slightly raised above the immediately surrounding part of the bottom of the calyx. An inconspicuous septal fossette occurs on the convex side of the corallum, occupied usually by one primary and two secondary septa. Dissepiments small and numerous, curving upward and outward between the septa and appearing in longitudinal sections as a dense vesiculose tissue. In cross-sections the septa vary between slightly convex and V-shaped on the side facing the exterior of the corallum.

Locality and position: All specimens here figured, except that represented by figure 2E, are from along the road north of Estill Springs, north of Irvine, Kentucky; figure 2E represents a specimen from east of Panola, along the road south of the railroad; specimens occur also half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine; two miles southwest of Clay City, along the road immediately north of Tipton Ferry; a mile southeast of Indian Fields, where the road from Kiddville enters the road from Indian Fields to Clay City, south of the railroad; a quarter of a mile south of Indian Fields, where the road crosses a small stream. In the Waco limestones, of Silurian age.

CYATHOPHYLLUM SEDENTARIUM, N. SP.

Plate 6, figs. 3A, 3B, 3C.

Corallum more or less flattened transversely, in extreme cases one of the horizontal diameters may equal fully twice that at right angles to it. The plane along which this flattening is most developed appears to be approximately lateral or diagonal to the plane of the septal fossette, but this can not be determined satisfactorily from the specimens at hand. This flattening appears to be connected with the method of support. In young specimens radiciform extensions of the epitheca appear to develop on the inclined side of the corallum, attaching the latter to some support. With increasing age this side of the corallum often developed to such an extent as to form a comparatively long and flat area of attachment bordered by the radiciform wrinkles of the epitheca. The growth wrinkles and striations

of the epitheca curve downward toward the distal end of the basal attachment. In addition to these specimens, considered more characteristic of the species, there are others which have ordinary pointed bases or narrow areas of attachment, with a few radiciform epithecal appendages farther up. In still other specimens no radiciform appendages were seen. Corallum marked by very irregular transverse wrinkles and growth lines, the result of calicular rejuvenation. Epitheca thin, strongly marked by transverse wrinkles and striæ and indistinctly marked by longitudinal low lines corresponding in number to the septa. Septa about 100, alternately larger and smaller, only the former reaching the center of the calyx, where the inner ends are slightly twisted. In some specimens no septal fossette could be detected, in others a very indistinct one appeared to extend obliquely toward the rear of the calyx. Calyx rather shallow; about 10 millimeters in depth. In most specimens the margin of the calyx slopes obliquely toward what is here called the front of the corallum. Dissepiments small and numerous, curved upward and outward in longitudinal sections, and slightly curved, strongly convex or even V-shaped in transverse sections. Along a very thin zone, in immediate contact with the epitheca, these small dissepiments are replaced by much larger ones, the concave surfaces of which are longitudinally lined with low septal ridges, while the septa frequently are more or less obsolete. In consequence, the moderately weathered coralla, from which only the epitheca has been removed, frequently resemble the weathered surfaces of species of Blothrophyllum. The extension of the septa to the center of the corallum, and the absence of large, strongly tabulæ in this part of the specimens is sufficient evidence that our specimens are not genuine specimens of *Blothrophyllum*. Tabulæ in our specimens are comparatively inconspicuous.

Locality and position: All specimens here figured came from along the road north of Estill Springs, north of Irvine, Kentucky; specimens occur also east of Panola, along the road south of the railroad; half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine. In the Waco limestone layers, of Silurian age.

Arachnophyllum. From *Vesicularia major* from the Silurian of Point Detour and Drummond Island, Michigan, our specimen is distinguished by the narrower and relatively deeper central depression and the distinct elevation of the calicular surface on approaching the rim of this depression.

Locality and position: Along the road north of Estill Springs, north of Irvine, Kentucky. In the Waco limestone layers, of Silurian age.

ARACHNOPHYLLUM (STROMBODES) GRANULOSUM, N. SP.

Plate 3, fig. 1.

Corallum compound, explanate, thin; only a part of the corallum is preserved in the specimen figured, and this shows a maximum width of 70 millimeters and a thickness of scarcely 3 millimeters. The lower surface is not exposed. Polyparia opening above in shallow calices meeting along polygonal outlines rising but slightly above the middle parts of the calyx. A very narrow, filiform line forms a border between the calices; this line is interrupted at intervals by minute pits or pores, situated most frequently at the ends of the grooves between the septal ridges. Calices about 7 to 10 millimeters wide along their longer diameters, and from 6 to 7 millimeters wide transverse to this direction. Very shallow depressions, from which the septal ridges radiate, occur in an excentric position, so that the calices have the appearance of opening obliquely upon the surface. It is not known to what extent this oblique position of the slight depression is characteristic of the species. Septal ridges average about 14 or 15 in number. These begin at the margins of the shallow depressions and radiate toward the margins of the calices; those toward the nearest or rear border widen rapidly and are more triangular in outline; those toward the farther or anterior border are more nearly linear; those on the sides curve toward the anterior border. These septal ridges are quite flat or only gently convex in a transverse direction, and are separated by narrow and rather shallow, but very distinct grooves. The surfaces of these septal ridges are marked by very minute granules. Somewhat coarser granules, very irregularly arranged, occupy the excentric depressed area. In some calices the margins of the depressed areas are slightly, or even distinctly

raised, producing the effect of a sharp circular border. In some cases the weathering away of one of the calicular layers leaves the depressed area of this layer distinctly above the general level of the next lower calicular surface. In vertical sections the corallites are seen to consist of successive calicinal floors supported by a rather coarse vesicular tissue, the cavities of which are rather wide but very shallow. Horizontal tabulæ, closely arranged, appear to cross the region corresponding to the central, depressed part of less excentric calices, but this part is not well exposed in the specimen at hand. Among the species so far described, this coral appears most nearly related to *Strombodes alpenensis*, Rominger.

Locality and position: Half a mile east of Waco, Kentucky, where the road to Cobb Ferry turns off from the Irvine pike. In the Waco limestone layers, of Silurian age.

Arachnophyllum (Strombodes) mamillare-distans, n. v.

Plate 3, figs. 2A, 2B, 2C.

Corallum discoid, flat, with mamiform cones representing the centers of the calices. Basal surface covered by a concentrically wrinkled epitheca, and with a small central point of attachment; in some specimens the epitheca shows also traces of radiating striæ which in width resemble the septal ridges on the upper surface of the corallum. In the largest specimen here figured, the original width of the fragment must have been at least 200 millimeters; the thickness between the mamiform cones was less than 15 millimeters, the centers of the mamiform cones rising in some cases fully 20 millimeters above the epithecal layer. At the top of each mamiform cone there is a well defined pit or crater, from 3 to 3.5 millimeters, occasionally 4 millimeters in diameter. Within this pit, about 18 radiating septa extend from the margin to a small central elevation or projection. Near the margin of the pit, the terminations of about the same number of short, additional septa may be seen. From these septa narrow rugæ pass over the margins of the pits and continue as approximately equal sized linear bands in a radiate direction from the pits across the areas between the cones. The different calicular areas are not separated by raised lines, obtuse elevations, changes of slope, or any other definite

structure. The number of radiating linear bands varies from 13 to 17 in a width of 10 millimeters. Their surfaces are marked by very minute granules. Horizontal sections show that the radiating septa do not extend beyond the margin of the pits. Vertical sections show the presence of a vesicular structure consisting of nearly horizontal lamellæ resting upon each other at irregular intervals; this structure is characteristic of by far the greater part of the corallum, being absent only in the central areas of the calices among the septa. Between the septa there are indications of dissepiments. The corallum is formed by a succession of numerous thin and closely applied calicinal layers, which show the radiating linear bands even on the inferior surface.

In the bed of a little stream a quarter of a mile south of Indian Fields a specimen was found 45 millimeters thick and 230 millimeters wide.

This variety differs from typical forms of *Arachnophyllum mamillare* in the smaller diameters of the calicinal pits and the greater distance between the mamiform cones.

Locality and position: Along the road south of the railroad, a short distance east of Panola station; also a quarter of a mile east of the home of Brownlow Bruner, north of the creek, along a road a mile southeast of Indian Fields, crossing the railroad and joining the road from Indian Fields to Clay City; also a quarter of a mile south of Indian Fields. At all localities, from the Waco limestone layers, of Silurian age. Figures 2A and 2C represent specimens from Panola; figure 2B represents a specimen from the Brownlow Bruner locality.

A small variety of *Arachnophyllum mamillare*, which may be known as *Arachnophyllum mamillare-wilmingtonensis*, occurs at Wilmington, and at other localities in the Dayton limestone of Ohio. This is the earliest representative of the species. The central pits of the mamiform cones have a diameter of 1.5 millimeters; the distance between the centers of the cones usually varies between 6 and 8, occasionally 10, millimeters. The septal rugæ radiating from the mamiform cones across the intercalicular spaces number about 8 or 9 in a width of 3 millimeters. This species was described as Lyellia striata, by U. P. James, in his Paleontologist, page 10, in 1878. It was formerly identified also as Strombodes pygmaeus, Rominger, in the Bulletin of Denison University, volume 3, page 120, in 1888.

CYSTIPHYLLUM SPINULOSUM, N. SP.

Plate 5, figs. 1A-1K.

Corallum simple; moderately curved or nearly straight. Length of specimens found so far less than 50 millimeters. Exterior of corallum covered by an epitheca which is marked by longitudinal grooves, dividing the surface into low, narrow linear ridges as in species having conspicuous septa; septa, however, obsolete. Of these longitudinal ridges, about six occur in a width of 5 millimeters. Exterior also with fine transverse, radiating striæ. Epitheca frequently absent, owing to weathering. In that case the vesicular structure is well exposed. Blister-like cavities, large and conspicuous, frequently 5 millimeters long and of equal or even greater width. The plates forming this vesiculose structure are convex above but concave as seen on the side of weathered surfaces of the coralla, since they curve upward and outward. The concave surface of these plates is marked by low longitudinal striations which correspond in frequency to the septal striæ on the exterior of the corallum. Calyx only partially exposed in the larger specimens at hand, apparently of moderate depth; formed by the convex sides of the uppermost layer of plates. In most specimens the convex side of these plates as exposed in the calyx is covered with coarse granules interspersed with smaller granules; these may take the place of the obsolete septa; in a few specimens they are arranged in approximately radiate lines; in others this arrangement can not be readily detected. While the usual appearance of these markings on the upper side of the plates is that of coarse granules, on well-preserved specimens they frequently are detected as short spines fully a millimeter in length. These spines have been seen in so many specimens that it is evident either that the coarse granules of weathered specimens represent the bases of the weathered spines, or that both spines and coarse granules occur in this species.

This species may be distinguished by the coarsely vesicular structure, the septal striations on the lower side of the plates, and the coarse granules and short spines on the upper side.

Locality and position: All the specimens figured except that represented by figure 1C, were found along the road north of Estill Springs, north of Irvine, Kentucky; figure 1C represents

a specimen found half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine; specimens occur also east of Panola, along the road south of the railroad. In the Waco limestone layers, of Silurian age.

CALOSTYLIS SPONGIOSA, N. SP.

Plate 7, figs. 3A-3G, and Plate 8, figs. 1A-1B.

Corallum sponge-like in appearance but provided with a distinct although very thin epitheca which usually is absent along the upper part of the corallum, and often even from almost the entire corallum, possibly due to removal by weathering. Coralla simple, attached at the base, forming irregular cylindrical or moderately conical growths. Septa numerous, the upper edges within the calyx irregularly toothed or crenulated; not readily distinguishable near the center of the calyx, where they form a spongy mass, but not a distinct columella. Septa perforated by numerous small openings or pores, and therefore cribiform. The sides of adjacent septa are attached to each other by numerous short, thin, irregular, rod-like bodies, called synapticula.

In the specimen represented by figure 3A, there are about 45 primary septa which may be traced down the walls of the calyx, but are replaced at the bottom of the calyx by a spongy structure not showing definite arrangement. Along the outer part of the corallum, secondary septa alternate with these primary ones. In figure 3B, there are 35 primary septa, with an equal number of secondary septa along the exterior of the specimen. In specimens having the diameter shown by figures 3C, 3D, 3E and 3G, the number of primary and secondary septa is about 90. In some specimens the septa are sharply defined and are distinctly perforated. In other specimens the structure is more confused and the term spongy septa appears to be more descriptive. Possibly this spongy appearance is due largely to the secondary septa. In the central part of the corallum the sclerites and synapticula form a confused sponge-like structure. Epitheca very thin; longitudinal septal rugæ not distinct in most specimens; transverse concentric striæ and wrinkles present.

The species here described assumes numerous forms. Some

of them, beginning with a narrow pointed base, expand rapidly into curved turbinate coralla as in species of *Zaphrentis* and *Cyathophyllum*. In some cases the growth is more sub-cylindrical. In other specimens the coralla are attached by rather broad bases to some other body, producing broad coralla of moderate height. The illustrations here presented show some of these variations.

Our specimens are closely related to the type species, *Calostylis denticulata*, Kjerulf, from the Silurian of Gotland, Sweden, from which it differs chiefly in the more numerous septa, in the distinctly smaller septal pores, and in the absence of branching, even in case of the largest coralla. Species of *Calostylis* have been described also from the Silurian of England. The exact affinities of this genus are still in dispute. Zittel placed it among the perforated madreporoid *Hexacoralla*, while Koken and Neumayr considered it an aberrant type of the rugose *Quadricoralla*.

Locality and position: The specimens here figured are all from along the road north of Estill Springs, north of Irvine, Kentucky; specimens occur also east of Panola, along the road south of the railroad; and half a mile east of Waco, where the road to Cobb Ferry starts off from the pike to Irvine; two miles southwest of Clay City, along the road immediately north of Tipton Ferry; one mile southeast of Indian Fields, south of the railroad, facing the creek, where the road from Kiddville joins the road from Indian Fields to Clay City. In the Waco limestone layers, of Silurian age.

The enlargements on plate 8 show traces of the synapticula and of the porous structure.

Pentamerus oblongus.

Plate 1, fig. 2.

In New York this species is not known outside of the Clinton fauna. In Ohio its first appearance is in the Dayton limestone, but here it is very rare. It occurs abundantly in the Springfield and Cedarville limestones.

The specimen here figured is from the Dayton limestone, about two miles west of Peebles, along the railroad. The specimen is symmetrical, but was inclined so as to show the details

better in a photograph. The largest fragment found at this locality indicates a specimen originally about 100 millimeters long; the trilobation of the valves is distinct, the outline of the shell more nearly resembling the form found in the Springfield and Cedarville limestones of Ohio than those predominating in the Clinton of New York. The specimen here figured is an interior cast showing the length of the median septum of the pedicle valve. In addition to the more distinct lobes, there are indistinct narrow folds, much less distinct than those of *Pentamerus oblongus-bisinuatus* from the Silurian of Wisconsin.

Locality and position: Two miles west of Peebles, in Adams county, Ohio. In the Dayton limestone, overlying the ferruginous layers of the Clinton. This horizon has not been traced into Kentucky as yet, but it probably corresponds approximately to the Oldham limestone forming the upper part of the Indian Fields formation, directly beneath the Alger clay.

STRICKLANDINIA NORWOODI, N. SP.

Plate 1, figs. 1A-1D.

The generic position of this shell is uncertain since the structure of the interior is only very imperfectly known, but the exterior form and the nearly obsolete bilaterally diverging plications resemble those of *Stricklandinia davidsoni* as figured by Billings.

Shells rather large, elongate-oval, with a hinge-line varying apparently between moderately curved and nearly straight. As far as may be determined from the specimens at hand, the hinge area of both valves is imperfectly exposed, if at all, the umbonal regions of the pedicle valves being more convex, and the beak more incurved. Both valves moderately convex, the convexity of the pedicle valve a little greater. It is estimated that the total thickness of a shell 38 millimeters in width is about 15 millimeters. Pedicle valve with a shallow median depression, beginning at the beak, where it is narrow, and extending forward and widening toward the middle of the shell. In some specimens this median impression disappears anteriorly, in others it becomes broader though remaining shallow. The brachial valve is marked by a low median elevation, narrow at the beak, becoming broader anteriorly. As far as the middle of the shell,

this median impression often is bordered on each side by a very shallow depression, giving greater distinctness to the elevation. Toward the anterior margin of the shell, however, both the elevation and the bordering depressions are likely to become indistinct. Both valves comparatively smooth, but showing traces of nearly obsolete broad radiating plications. The latter are sometimes crossed by additional plications having a distinctly bisymmetrical arrangement, apparently curving from the median part of the shell somewhat forward and more strongly toward the lateral part of the shell, so as to cross the nearly obsolete radiating plications. In the specimen represented by figure 1D the radiating plications are readily seen when the valve is held at the proper angle. In specimens represented by figures 1A and 1C the bilaterally divergent crossing plications are seen.

In one of the pedicle valves, broken off at the beak, is seen a cross-section of a V-shaped structure supported by a vertical plate resting on the inner side of the valve. This is interpreted as a spondylium resting on a median septum. In a cast of the interior of this valve this septum appears to have extended to a point 8 millimeters anterior to the hinge-line. The spondylium appears to have been folded so as to form a V-shaped groove and to have extended forward and away from the umbonal part of the shell. The spondylium was short, probably 8 millimeters or less in length.

The cast of the interior of a brachial valve shows two short grooves extending from the beak forward for a distance of 5 millimeters, slightly diverging, their anterior ends about a millimeter and a half apart. On the exterior side of each groove the cast is slightly raised, forming a short narrow ridge. Immediately anterior to these nearly parallel grooves the posterior ends of two narrow muscular scars apparently are found. This structure of the brachial valve apparently agrees best with that shown by *Stricklandinia castellana* from the Silurian of Iowa, as figured by Hall and Clarke, in the eighth volume of the Paleontology of New York, plate 73, figure 7.

Locality and position: All of the specimens figured were found about five and a half miles south of Indian Fields, along the road to Vienna, a short distance south of the culvert southeast of the home of J. T. Elkins. Similar specimens are abundant three miles south of Indian Fields, east of Long Branch; a

mile west of Indian Fields, west of Howard Creek, along the railroad; three miles southwest of Clay City, along Plum creek; along the road north of Estill Springs, north of Irvine; along the railroad between Brassfield and Panola, and elsewhere. The last named locality shows good exposures at the proper horizon, although the best specimens found so far came from the J. T. Elkins locality. The species occurs widely distributed at the top of the Oldham limestone layers. The Oldham limestones are typically exposed aong the railroad following the north side of the valley of Oldham creek, between Brassfield and Panola, and here the species may be found readily. It is the most characteristic and most widely distributed shell of the Oldham limestones studied so far. I take great pleasure in naming it after the present head of the Geological Survey of Kentucky, Prof. C. J. Norwood, to whom I am under obligation for encouragement and assistance.

Figures 1A, 1C and 1D represent pedicle valves; figure 1B represents a brachial valve; figure 1D was taken from the shell; the other figures were taken from the natural casts of the interior.

Whitfieldella subquadrata, Foerste.

Plate 1, figs. 3A-3F.

Shells abundant in the form of casts of the interior showing the muscular scars and the impressions of the teeth and other structures along the hinge-line. It is closely related to Whitfieldella cylindrica, and may be regarded merely as a variety of the latter. Compared with typical forms of Whitfieldella cylindrica, however, it is a much more robust shell, less elongate, broader at the beak, with no median depression along the pedicle valve and with no sinuate flexure of the shell on approaching the anterior outline. The name *subquadrata* was suggested by shells having the outline represented by figure 3B of which 3A is a cardinal view, with the pedicle valve on the lower side. Subsequently shells having a more oval outline were found to be not rare so that the name originally suggested has lost its value as a descriptive designation of the species.

Interior casts of the pedicle valve strongly marked by a strongly elevated triangular cast of the deep diductor muscular

scar, on each side of which are a series of parallel transverse rugæ, occupying the area in other shells often showing ovarian markings. The cast of the brachial valve shows the presence of a deeply concave hinge plate anterior to which is a short median septum.

Locality and position: All of the specimens figured were obtained about four miles west of Berea, along the lower part of Rocky Branch. The species, however, is widely distributed along the eastern side of the Cincinnati geanticline, from Spencer, Kentucky, to Stamford, and again along the lower part of Fishing creek and along the Cumberland river, at the mouths of Forbush and Little Cub creeks, within twenty miles toward the west of Somerset, Kentucky. It is the most characteristic shell of the limestone layers immediately overlying the Brassfield limestone and forming the base of the Indian Fields formation, just beneath the clays of the Plum creek horizon.

WHITFIELDELLA QUADRANGULARIS, FOERSTE.

Plate 1, figs. 4A, 4B, 4C.

This shell may be regarded as a variety of Whitfieldella crassirostra, from the Silurian of New York, but the shell is somewhat broader at the hinge-line and the anterior margin is not strongly sinuate, the median depression of the pedicle valve being rather slight. This depression, as a rule, is seen only along the anterior half of the pedicle valve. A very faint, scarcely distinguishable median depression sometimes occurs along the corresponding parts of the brachial valve. It is a much less robust shell than Whitfieldella subquadrata, to which it is evidently closely related.

Locality and position: All of the specimens figured were obtained northeast of Duncansville, east of Sprows bridge, up a ravine on the north side of the road, 38 feet above the base of the Clinton, in Adams county, Ohio. Similar specimens were found in the western part of the county, south of Winchester. It should occur in the northern part of Kentucky, but has not been discovered as yet.

CHONETES VETUSTA, N. SP.

Largest ventral or pedicel valve about 15 millimeters wide and 6 millimeters long, gently convex; surface marked by about

60 or 70 radiating striæ; hinge line with rather long and divergent fimbriate spines, the longest about 1.5 millimeters in length. None of the specimens show all of the spines, but their number is probably about 2 or 3 on each side of the beak.

Apparently a distinct species, differing from *Chonetes cornuta*, Hall, and *Chonetes undulata*, Hall, in the greater number of radiating striæ. *Chonetes tenuistriata*, Hall, is about of the same size, but has nearly 100 striæ. *Chonetes novascotica*, Hall, is a larger shell, with more than 100 striæ, with 4 or 5 rather short cardinal spines on each side of the beak, and, often, with a flattened or slightly concave space down the middle of the valve. *Chonetes novascotica-waldronensis* usually is a smaller shell, with 2 or 3 rather long cardinal spines, and with the median striation characteristically prominent.

Locality and position: In the shaly limestone, at the top of the Alger clay, of Silurian age, up the hill, north of the home of Alfred Huffman, less than a mile west of Valley, about 8 miles west of Vanceburg, Kentucky.

ISOCHILINA PANOLENSIS, N. SP.

A large species of Ostracod is characteristic of the Waco limestone in East-Central Kentucky. It is most closely related to *Isochilina grandis-latimarginata*, Jones, from the Silurian of Lake Winnepegosis and the Saskatchewan river of Canada. There is, however, scarcely a perceptible trace of an ocular tubercle or of a sulcus. The dorsal margin is straight, and the dorsal angles are definite, although very obtuse. There is no slight emargination of the anterior and posterior margins just before reaching the dorsal line, as in *Isochilina grandis-latimarginata*, but in other respects the outline is closely similar, although, in some specimens, the greatest convexity of the posterior margin is slightly nearer the ventral border.

Our specimens are smaller than *Isochilina grandis-latimarginata;* the usual length is 8 millimeters, but some specimens 10 millimeters long are found. The ventral border of the left valve is deflected strongly downward along the entire length of the valve, making an angle of about 80 or 85 degrees with the general plane of the valve. In one specimen the width of this deflected border is fully .75 millimeters, but this width dimin-

ishes gradually toward the anterior and posterior margins. Held at a favorable angle, a slight elevation of the margin of the upper surface of the valve may be seen just before reaching the deflected border. The valves are convex, the convexity being distinctly greater at a point about two-fifths of the length of the shell from the anterior margin. From this area the shell slopes rather evenly to the anterior and posterior margins, or is faintly concave just before reaching the slightly elevated, very narrow rim. There is no flat marginal rim distinctly defined from the general convexity of the main body of the valve, as in *Isochilina grandis-latimarginata.*

Length of hinge-line of left valve, 5.3 millimeters; greatest length across middle of valve, 7.8 mm.; greatest vertical diameter across middle of valve, 5mm. Some specimens attain a length of 10 millimeters. Surface smooth. Most of the valves found are left valves. One of the right valves differs in form, having a more oblique ventral margin. Its dimensions are: Length of hinge-line, 4.1 millimeters; greatest length of shell, 7.5 mm.; width across posterior third of valve, 5.4 mm.; width across anterior third, 4.6 mm.

Locality and position: Rather abundant at Panola, east of the station, south of the railroad; found also north of Irvine, east of the road passing Estill Springs, a short distance before reaching White Oak creek. Characteristic of the Waco limestone horizon.

BEYRICHIA LATA-TRIPLICATA, NOV. VAR.

In the Paleontology of New York, volume 2, page 301, published in 1852, Prof. James Hall published descriptions of a species of Bollia and of a species of Beyrichia under the same name Beyrichia lata, erroneously regarding these distinct species as opposite valves of the same species. Of these species the Beyrichia is described first, but on plate A66 the Bollia is figured first. In the catalogue of types and figured specimens in the American Museum of Natural History, at New York, Whitfield and Hovey have referred all of the types to Bollia lata, Hall. We prefer to apply the name Bollia lata to the species represented by figure 10b; and to use also the name Beyrichia lata, Hall, restricting this designation to the species

illustrated by figures 10c, d, e, of plate A66. With this interpretation, Beyrichia lata, Hall, differs from Beyrichia æquilatera, Hall, chiefly in the much narrower marginal border, elevated so as to form a narrow, distinctly defined rim. Beyrichia lata seems to be a distinctly larger species than Beyrichia æquilatera. Prof. Rupert T. Jones, in Part III of the Contributions to Canadian Micro-Paleontology, published in 1891, described one specimen as having a length of 1.5 mm. The figure of Beyrichia lata, in figure 10a, on plate A66, of the Paleontology of New York, however, is fully 2.75 mm. long.

In the upper part of the Alger clay in Lewis county, Kentucky, southwest of Vanceburg, at Valley opposite the home of W. A. McEldowney, a species of Beyrichia occurs in thin plates of argillaceous rock interbedded with the clays. The same species of Beyrichia occurs also up the hill, back of the home of Alfred Huffman, and at other localities at the same horizon, along the road to the W. H. Lawrence store. This species of Beyrichia varies in length from 2.5 to 3 millimeters. In the best preserved specimen, a right valve, the length is 2.5 mm.; height, 1.8 mm. This species is closely related to Beyrichia lata, Hall, but differs in having a distinctly shorter hinge-line, about 1.9 or 2 millimeters in a valve 2.5 millimeters long. The anterior and posterior dorsal angles, instead of being approximately rectangular, are very obtuse, owing to the convex outline of the anterior and posterior margins. The narrow marginal rim is distinct, and is separated from the body of the valve by a narrow groove. The body is trilobate. Of these lobes, the central is the narrowest; the anterior lobe is only slightly larger, but the posterior lobe is considerably larger. All of these lobes rise to approximately the same elevation, and are separated by deep grooves. The middle lobe narrows ventrally and approaches to within a short distance of the groove within the marginal rim, being separated from this groove only by the very narrow ridge connecting the anterior and posterior lobes. If the New York specimens have been figured correctly, our specimens form a distinct variety, distinguished by the greater curvature of the anterior and posterior outlines of the valves, resulting in a shorter hinge line.

Locality and position: Near top of Alger clay, at various localities in Lewis county, Kentucky, from Valley westward as far as the Lawrence store.

PLATE 1.

Figs. 1A-1D. STRICKLANDINIA NORWOODI, nov. sp.

A, C, D. Views of natural casts of pedicle valves.

B. Cast of brachial valve.

A and C show the characteristic, very faint, bilaterally divergent wrinkles; D shows the very faint radiating wrinkles. In C, the anterior outline is not preserved and the original specimen may have been longer. The anterior outline of D is restored also. B shows the slight median elevation of the brachial valve. There is a corresponding slight median depression in the pedicle valves, not well shown in any of the figures.

Oldham limestone, near the top; Silurian; found along the road to Vienna, five and a half miles south of Indian Fields, near the home of J. T. Elkins, in Madison county, Kentucky.

Fig. 2. PENTAMERUS OBLONGUS, Sowerby.

Pedicle view, showing the long septum (which supports the spondylium in this genus).

Dayton limestone, overlying the rock identified as Clinton in Ohio. Found along the railroad, two miles west of Peebles, in Adams county, Ohio.

Figs. 3A-3F. WHITFIEDELLA SUBQUADRATA, Foerste.

A. Internal cast of shell near the hinge; cast of brachial valve in upper part of figure, cast of pedicle valve in lower part. The latter shows the cast of the deep muscular depression and the strong corrugations of the shell on both sides of this depression; these features are seen also in 3B and 3D.

B, E, F. Views of the casts of the pedicle valves.

C. Cast of the brachial valve.

D. Lateral view of cast; with pedicle valve on right, and brachial valve on left.

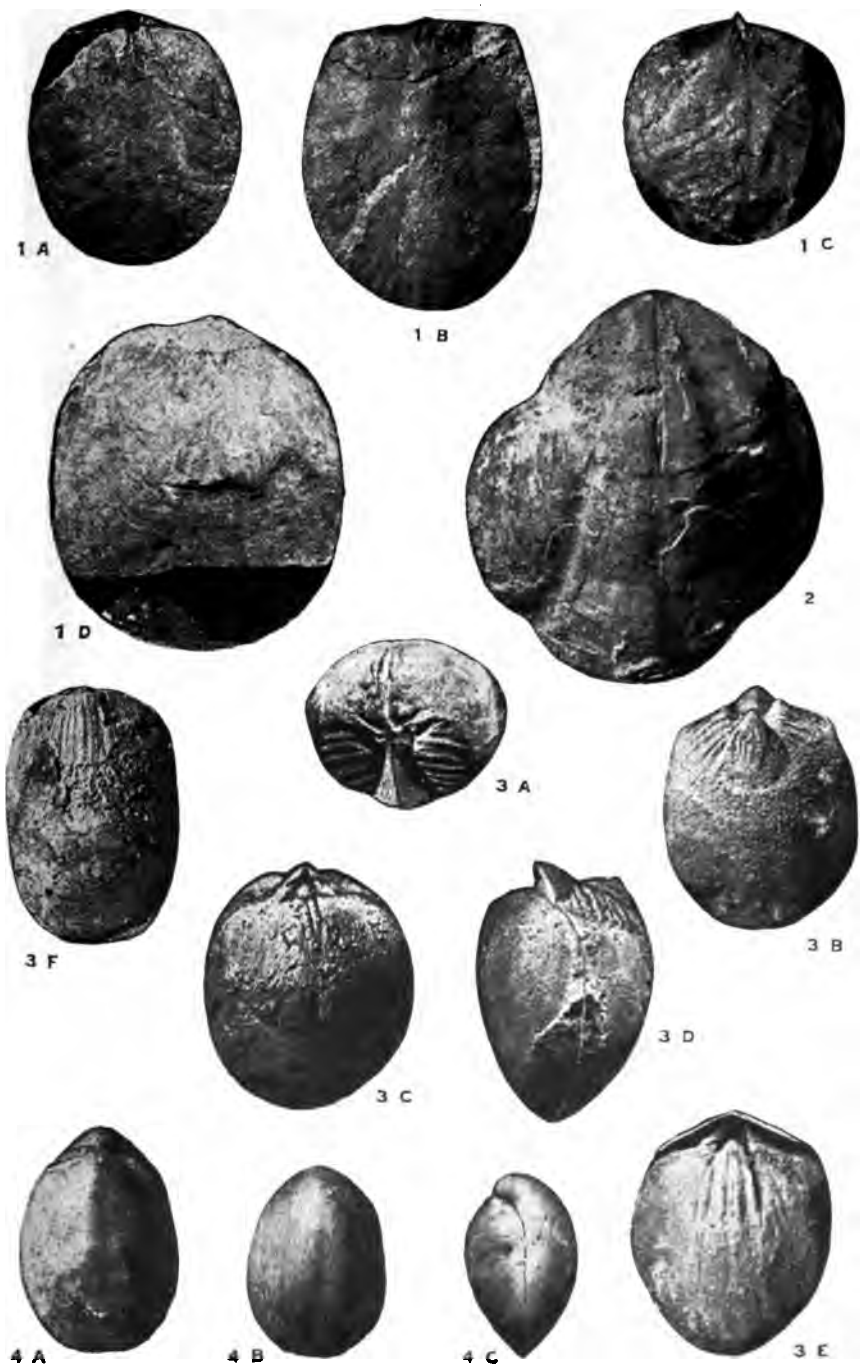
Found at base of Indian Fields formation, Silurian; on Rocky branch, four miles west of Berea, Ky.

Figs. 4A-4C. WHITFIELDELLA QUADRANGULARIS, Foerste.

A. Brachial view.

B. Pedicle view.

C. Lateral view, with pedicle valve on right. Found 38 feet above the base of the rock identified as Clinton in Ohio; northeast of Duncansville, in Adams county, Ohio.



Silurian Brachiopods

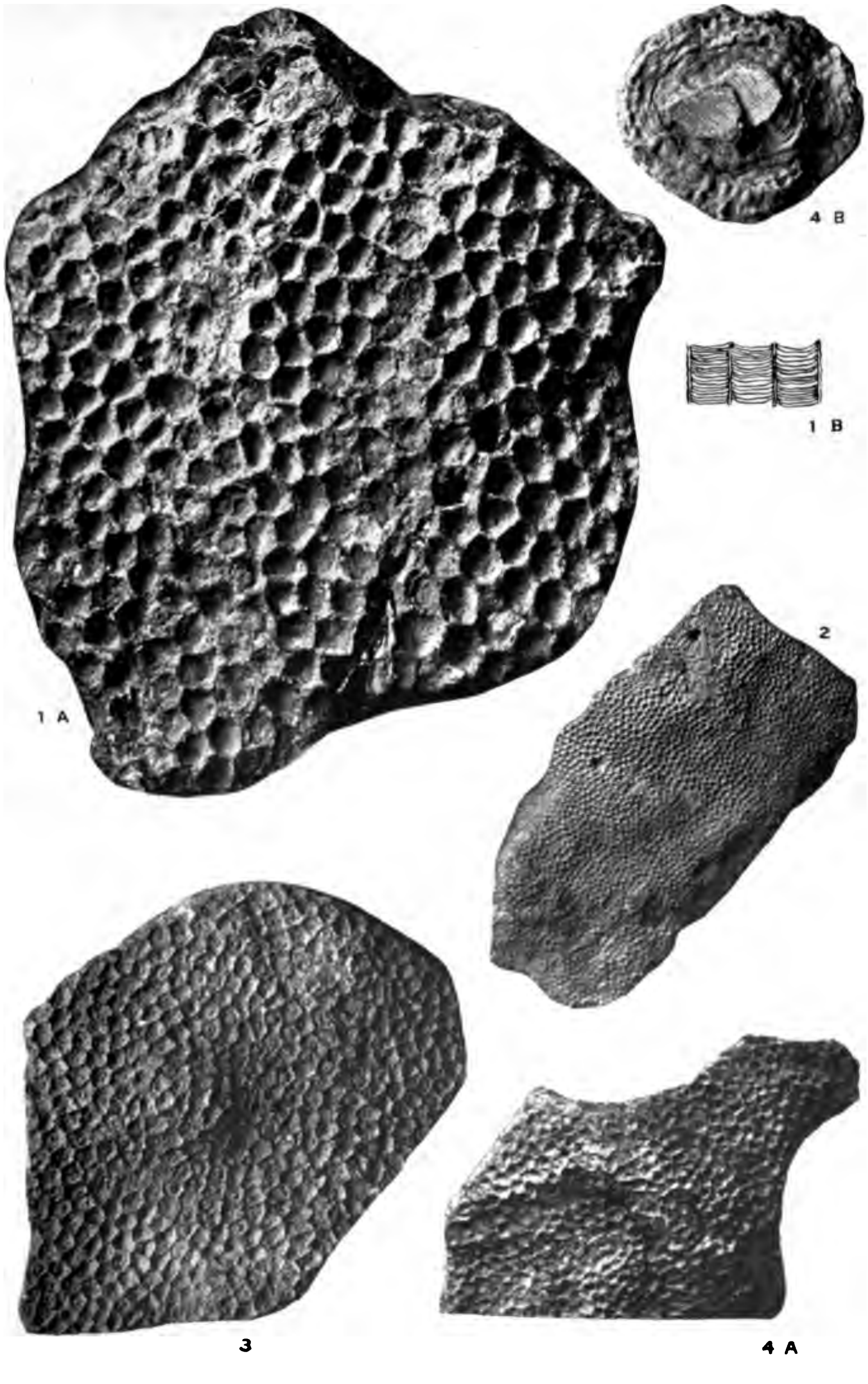
PLATE 2.

Figs. 1A-1B. FAVOSITES GOTHLANDICA, Lamarck.
A. Upper surface
B. Vertical section, showing numerous tabulæ.
Waco limestone, Silurian; Irvine, Ky.

Fig. 2. FAVOSITES HISINGERI-APLATA, nov. var.
Waco limestone, Silurian; Irvine, Ky.

Fig. 3. SYRINGOLITES HURONENSIS, Hinde.
Waco limestone, Silurian; Tipton Ferry, Ky.

Figs. 4A-4B. FAVOSITES DECLINATA, nov. sp.
A. Upper surface.
B. Lower surface, with epitheca.
Waco limestone, Silurian; Irvine, Ky.



Silurian Corals

PLATE 3.

Fig. 1. ARACHNOPHYLLUM (STROMBODES) GRANULOSUM, nov. sp.
Waco limestone, Silurian; near Waco, Ky.

Figs. 2A-2C. ARACHNOPHYLLUM (STROMBODES) MAMILLARE-DISTANS, nov. var.
A, B. Crater at top of cone-shaped prominences sharply defined.
C. Crater rounding off into sides of cone.
Waco limestone, Silurian; 2A, 2C, Panola, Ky.; 2B, Brownlow Bruner locality, Kentucky.

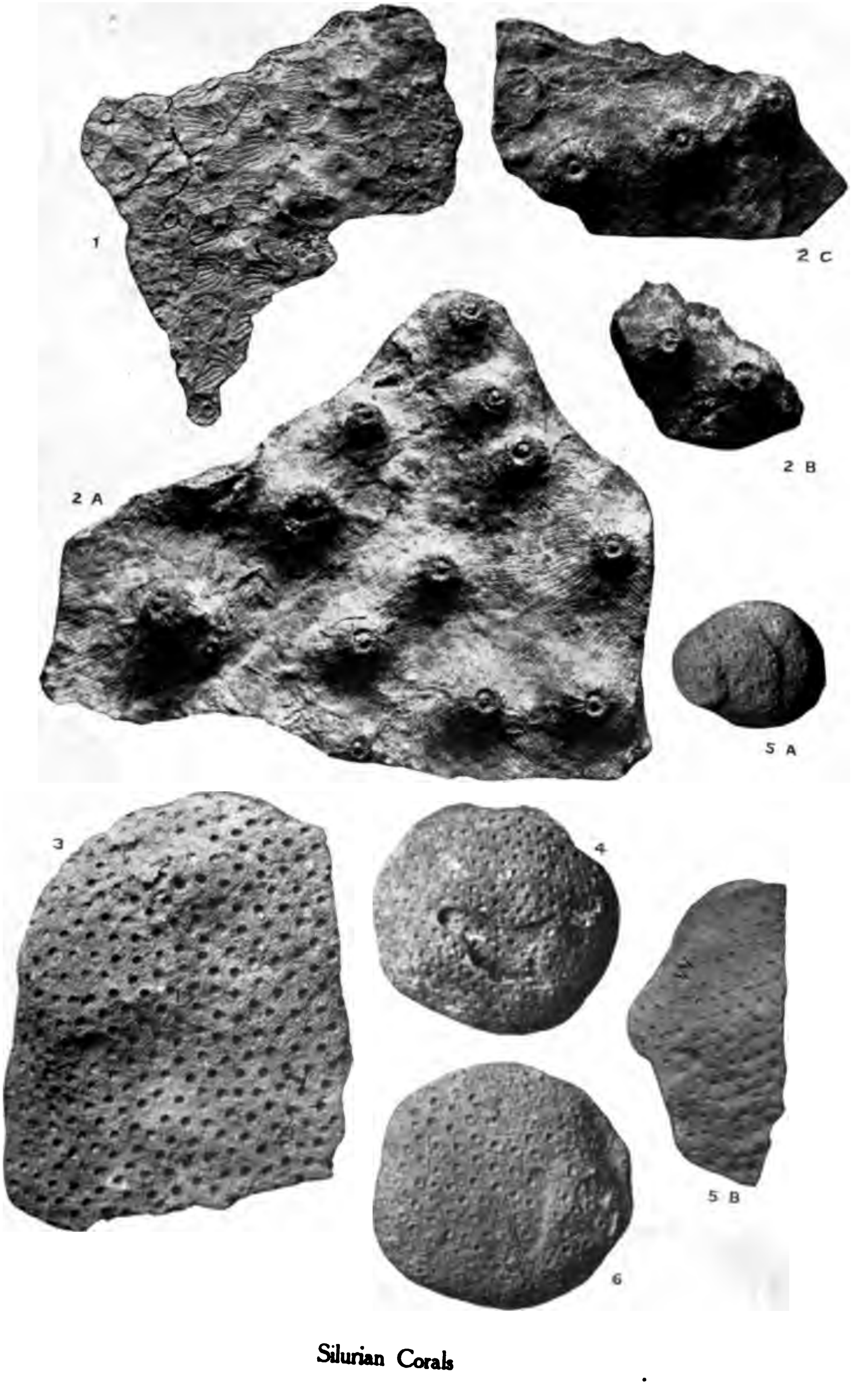
Fig. 3. HELIOLITES SPONGIOSA, nov. sp.
Waco limestone, Silurian; along road north of Estill Springs, near Irvine, Ky.

Fig. 4. HELIOLITES, sp.
Waco limestone, Silurian; road north of Irvine, Ky.

Fig. 5A. HELIOLITES SUBTUBULATA-NUCELLA, nov. var.
Waco limestone, Silurian. A small form, increasing in height without much lateral expansion, from Irvine, Ky.

Fig. 5B. HELIOLITES SUBTUBULATA-DISTANS, nov. var.
A flat, explanate form, from the Waco limestones, half a mile east of Waco, Ky.

Fig. 6. LYELLIA EMINULA, nov. sp.
Waco limestone, Silurian; along road north of Estill Springs, north of Irvine, Ky.



Silurian Corals

PLATE 4.

Fig. 1. LYELLIA, sp.
Flat variety, possibly distinct from Lyellia eminula.
Enlarged 3 diameters. Same specimen as plate 5, figure 4.
Waco limestone, Silurian; east of Waco, Ky.

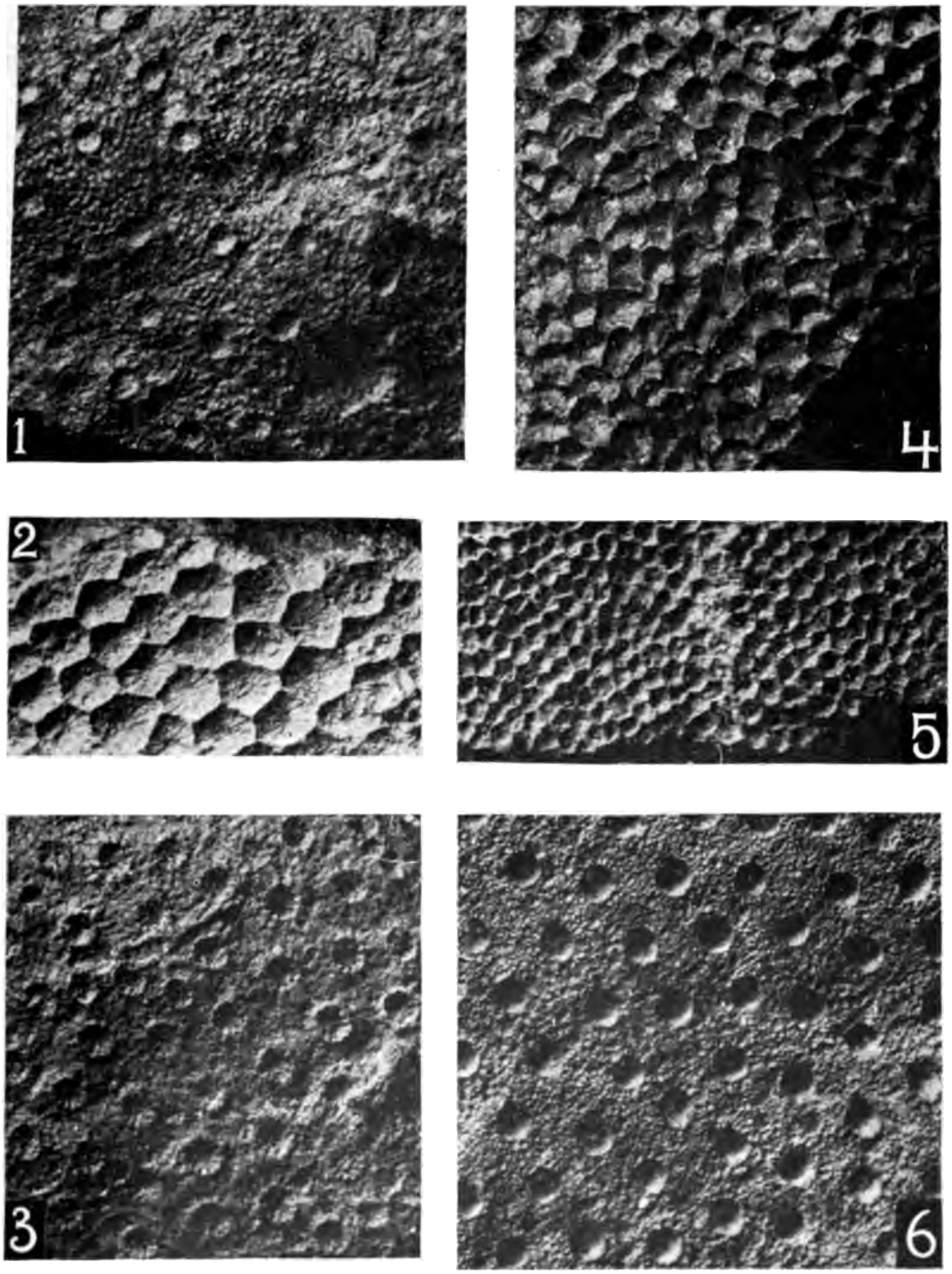
Fig. 2. SYRINGOLITES HURONENSIS, Hinde.
Enlarged 3 diameters. Same specimen as plate 2, figure 3.
Waco limestone, Silurian; Tipton Ferry, southwest of Clay City, Ky.

Fig. 3. LYELLIA EMINULA, nov. sp.
Enlarged 3 diameters. Same specimen as plate 3, figure 6.
Waco limestone, Silurian; north of Irvine, Ky.

Fig. 4. FAVOSITES DECLINATA, nov. sp.
Enlarged 3 diameters. Same specimen as plate 2, figure 4A.
Waco limestone, Silurian; along road north of Estill Springs, north of Irvine, Ky.

Fig. 5. FAVOSITES HISINGERI-APLATA, nov. var.
Enlarged 3 diameters.
Waco limestone, Silurian; along road north of Estill Springs, north of Irvine, Ky.

Fig. 6. HELIOLITES SPONGIOSA, nov. var.
Enlarged 3 diameters. Same specimen as plate 3 figure 3.
Waco limestone, Silurian; north of Irvine, Ky.



Silurian Corals

PLATE 5.

Figs. 1A-1K. CYSTIPHYLLUM SPINULOSUM, nov. sp.

A, B, C, G. Specimens showing the general form of the corallum.

A, D, F. Specimens showing the large vesiculose plates or dissepiments with the vertical septal ridges.

A, H, J, K. Specimens showing the septal ridges on the exterior of the epithecal covering.

E. Specimens showing the papillose upper surface of the vesiculose plates. In the best preserved specimens these are preserved as short spines.

Waco limestone, Silurian. All except 1C are from the road north of Estill springs, north of Irvine, Ky.; 1C was found half a mile east of Waco, Ky.

Figs. 2A-2F. LINDSTROEMIA LINGULIFERA, nov. sp..

A, B, D. Views of base of calyx; margin of calyx not preserved.

C. Lateral view, showing linguliform process.

E, F. Lateral and posterior views.

Waco limestone, Silurian; 2A, 2B, from Panola, Ky.; all other specimens from along road north of Estill Springs, north of Irvine, Ky.

The linguliform process of this species resembles that of *Lindstroemia dalmani*, Edwards and Haime, from the Upper Silurian of Gotland, Sweden.

Figs. 3A-3E. POLYOROPHE RADICULA, nov. sp.

A, B. Enlarged views of a specimen showing the septal rows of granules on the upper surface of the tabulæ. Specimen cylindrical, the conical appearance due to the angle at which it was photographed.

C, D, E. Lateral views of typical specimens.

Fig. 4. LYELLIA, sp., flat variety, possibly distinct from Lyellia eminula.

A small part of the upper surface, enlarged.

Waco limestone, Silurian; half a mile east of Waco, Ky.

Fig. 5. HELIOLITES, SPONGIOSA, nov. sp.

A small part of the type specimen (plate 3, figure 3), enlarged.

Waco limestone, Silurian; north of Irvine, Ky.

Silurian Corals

PLATE 6.

Figs. 1A-1B. MEEKOPORA BASSLERI, nov. sp.

A. The usual form of the fragments found, four-thirds of natural size.

B. A branching frond, with the sides of the branches not showing the usual parallel outlines.

Waco limestone, Silurian; along the road north of Estill Springs, north of Irvine, Ky.

Figs. 2A-2F. CYATHOPHYLLUM DENSISEPTATUM, nov. sp.

A, B, C. Views of typical specimens.

D, E, F. Possibly young specimens of the same species.

Waco limestone, Silurian; all specimens except 2E were found along the road north of Estill Springs, north of Irvine, Ky.; 2E was found immediately east of Panola, Ky.

Figs. 3A-3C. CYATHOPHYLLUM SEDENTARIUM, nov. sp.

A. The typical form, showing the radiciform extensions of the epitheca where attached to a horizontal object; these radiciform extensions sometimes are more strikingly developed.

B, C. Specimens showing broad dissepiments striated vertically by septal striæ or ridges, the septa being absent. This structure is charateristic of the parts nearest the epithecal surface.

Waco limestone, Silurian; on the road north of Estill Springs, north of Irvine, Ky.

PLATE 7.

Figs. 1A-1B. ZAPHRENTIS INTERTEXTA, nov. sp.

A. View of calyx.

B. Lateral view.

Waco limestone, Silurian; along road north of Estill springs, north of Irvine, Ky.

Fig. 2. CHONOPHYLLUM SOLITARIUM, nov. sp.

View of calyx; margin of specimen imperfectly preserved.

Waco limestone, Silurian; road north of Estill Springs, north of Irvine, Ky.

Figs. 3A-3G. CALOSTYLIS SPONGIOSA, nov. sp.

A, B, C. Views showing calyx.

D, E, F, G. Lateral views showing epithecal surface.

F, G. Attached by broad bases to other fossils.

Waco limestone, Silurian; road north of Estill Springs, north of Irvine, Ky.

Figs. 4A-4E. ZAPHRENTIS CHARAXATA, nov. sp.

A, D. View of calyx, and lateral view of same specimen; margin of calyx preserved only along the septal fossette.

B, C. Views of base of calyx, sides not preserved.

E. View of exterior, showing the characteristic markings of the surface when slightly worn.

Waco limestone, Silurian; along road north of Estill Springs, north of Irvine, Ky.

Figs. 5A-5B. ZAPHRENTIS INTERTEXTA-IRVINENSIS.

A. View of base of calyx, sides not preserved.

B. Lateral view, walls of calyx not preserved.

Waco limestone, Silurian; road north of Estill Springs, north of Irvine, Ky.

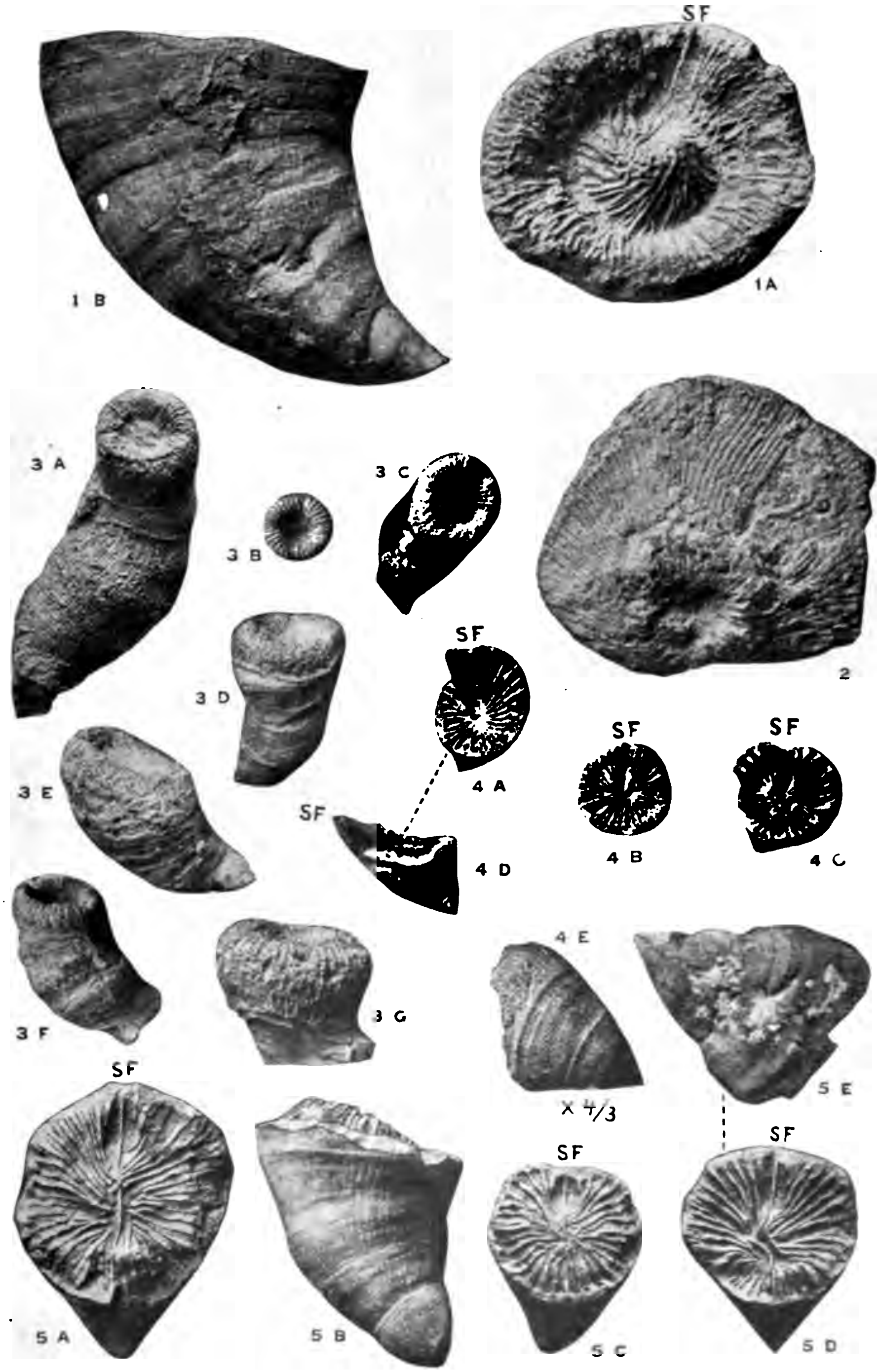
Figs. 5C-5E. ZAPHRENTIS INTERTEXTA-JUVENIS.

C, D. Views of calyx, walls not preserved.

E. Posterior view of D, showing numerous transverse striæ crossing the low vertical ridges.

Waco limestone, Silurian; north of Irvine.

The position of the septal fossette is indicated by SF.



Silurian Corals

PLATE 8.

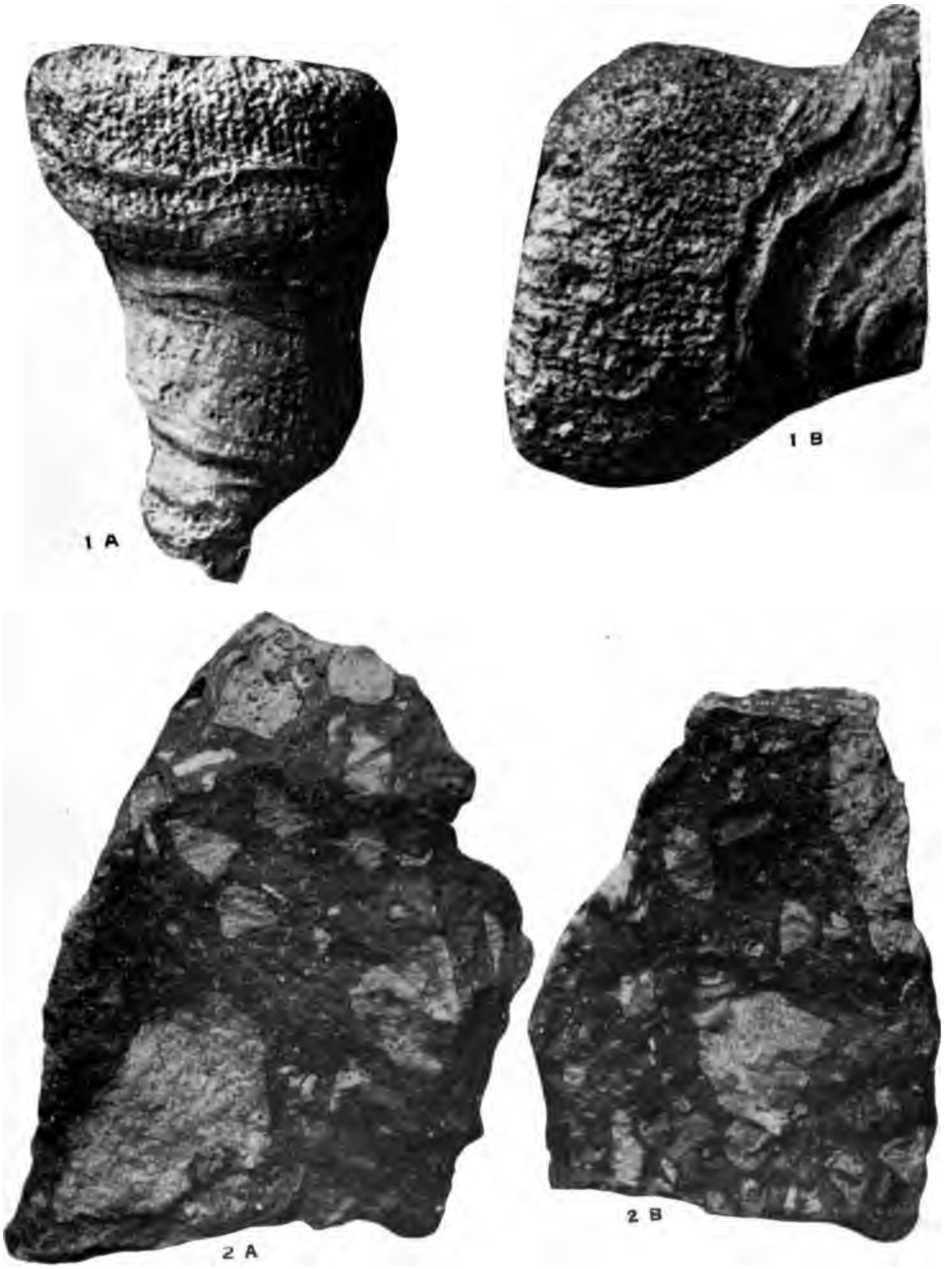
Figs. 1A-1B. CALOSTYLIS SPONGIOSA, nov. sp.

Enlarged 3 diameters. 1A, same as plate 3, figure 3D; the porous structure produced by the junction of the synapticula from adjacent septal plates is shown in the upper part of the figure, between 25 and 35 millimeters toward the left of the upper right hand corner of the figure. 1B, same specimen as plate 3, figure 3G; synapticula are well shown 21 millimeters below the top of the figure, and 28 millimeters from the right; others are shown along a septal ridge 30 millimeters below the top; synapticula are present also elsewhere in the figure, but their relation to the septal plates is not well brought out owing to the angle at which the specimen was illuminated.

Waco limestone, Silurian; north of Irvine, Ky.

Figs. 2A-2B. Duffin limestone, showing the brecciated appearance characteristic of this rock at numerous exposures in central Kentucky.

A small part of the metric scale used by scientists in making measurements of fossils and other objects is here added. The smallest divisions indicated are millimeters. Each group of 10 millimeters forms a length called one centimeter. The centimeters of this scale are numbered.



Silurian Corals. Duffin Rock—Devonian.

Milli-meter Scale.

GENERAL INDEX.

A. GENERAL INDEX.

B. FORMATIONS.

C. LIST OF LOCALITIES.

1. Geographical Names.

2. Personal Names.

D. Index to Locality Numbers Used on the Accompanying Maps.

The letters are printed in a conspicuous manner on the maps cited below, and follow the numbers specifying the localities described in this bulletin. In order to find the location of any locality upon the map, first find the page on which the map is printed; then find the large letters designating the particular section upon which the number has been placed. Within the boundaries of this section the number may be found easily. In the Stanford-Crab Orchard map, the quadrangles are named instead, but the names for these quadrangles are given also in this index. In order to find the page on which the exposures at the locality indicated are described, look up the page number in the index below.

Crab Orchard quadrangle, northeast section. (See map on page 140, left side of the map.)

London quadrangle, northwest section. (See map on page 140, lower sixth of page.)

Harrodsburg quadrangle, south section. (See map on page 140, upper left-hand corner.)

Harrodsburg quadrangle, southeast section. (See map on page 140, upper, V-shaped segment.)

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Richmond quadrangle, southwest section. (See map on page 155.)

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Richmond quadrangle, south section. (See map on page 167.)

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Richmond quadrangle, southeast section. (See map on page 173.)

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Richmond quadrangle, east section. (See map on page 173.)

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Richmond quadrangle, northeast section. (See map on page 185.)

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Beattyville quadrangle, west section. (See map on page 173.)

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Beattyville quadrangle, northwest section. (See map on page 193.)

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Flemingsburg quadrangle. (See map on page 202.)

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